ONTARIO HARDWOOD DECLINE SURVEY 1989 AND 1990

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1989 AND 1990

Report prepared for:

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Report prepared by:

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EXECUTIVE SUMMARY

A hardwood decline survey was conducted in 1989 and 1990 to reassess the status of deciduous forest decline in Ontario. Previous surveys were conducted in 1986 and 1987. The work was carried out under contract to the Phytotoxicology Section of the Air Resources Branch, Ministry of the Environment by Beak Consultants Limited.

The survey consisted of visual evaluations of tree condition at 110 permanent plots, each containing 100 trees greater than 10 cm dbh.

Tree decline was assessed with a numerical decline index (DI) rating system which ranged from 0 (healthy, no symptoms) to 100 (dead tree). The mean DI of hardwood trees was 11 in 1989 and 13 in 1990. By comparison, the mean DI in 1986 and 1987 was 14 and 15, respectively. All of these values represent relatively low decline.

A Geographic Information System was used to assess the spatial distribution of forest decline in the Province. Severe hardwood decline (DI greater than 25) was found in 3 plots in 1990; 7 plots in 1989, 10 plots in 1987 and one plot in 1986. The Sudbury MNR Administrative District was the only District to contain plots which showed consistent and severe decline in 1987, 1989 and 1990.

Between 1989 and 1990, 91% of all plots either had no mean change or increased/decreased by one decline class. An increase in DI implies a deterioration in tree condition. This compares with 78% between 1987 and 1990, 90% between 1986 and 1990, 72% between 1987 and 1989, 82% between 1986 and 1989 and 83% between 1986 and 1987. The greatest change in tree condition occurred between 1987 and 1989, with 28% of the plots reporting a change in DI of more than one decline class. The least amount of change in tree condition (9%) occurred between 1989 and 1990.

Most of the change in decline occurring between 1987 and 1989 was reported in the Sudbury and Algonquin Park MNR Districts. Mean plot DI decreased by four decline

classes at single plots within each of these two MNR Districts. Mean plot DI decreases of three decline classes were also recorded at two plots within the Algonquin Park District, and at individual plots in the Bracebridge, Cornwall, Owen Sound, Pembroke and North Bay MNR Districts.

The most substantial change in individual mean plot DI between 1989 and 1990 occurred in the Parry Sound MNR District (Plot 18), where there was a decrease of three decline classes. Increases in mean plot DIs of two decline classes occurred at individual plots in the Parry Sound, Tweed and Napanee MNR Districts. Decreases in average plot DIs of two decline classes were recorded at two plots in both the Parry Sound and Sudbury MNR Districts, and at single plots in each of the Espanola and North Bay MNR Districts.

Tree mortality across all survey plots was 1.7% in 1986, 3.1% in 1987, 1.1% in 1989 and 1.5% in 1990. The total number of dead trees increased from 1986 to 1987, and from 1989 to 1990. There was a substantial decrease in the number of trees classed as dead from 1987 to 1989. The number of dead trees in 1986 was also higher than in 1989 and 1990. It is probable that many of the trees noted to be dead in 1986 and 1987 were so classified due to extensive defoliation.

Almost one-quarter of the dead sugar maple identified in the 1989 survey were found in the Minden MNR District. The Parry Sound and Espanola Districts each contained roughly 10% of the total 1989 dead sugar maple. The remaining dead maple were scattered in small numbers throughout the rest of the study area. In 1990, dead sugar maple were more evenly distributed across the Province. Aylmer District had the highest percentage of dead maple within Ontario at 8.9%. The North Bay and Niagara Districts both had the next highest percentage at 7.9%.

No consistent relationship was established in any survey year between the areas of hardwood forest decline and wet sulphate and nitrate deposition.

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1.0 INTRODUCTION

1.1 General Background

Forest decline is not a new phenomenon; rather, it has been recorded worldwide for more than a century (Cowling, 1985). However, within the last decade, an unprecedented number of severe declines have been reported in many European countries and parts of North America.

Forest declines in Europe were first noted for silver fir (Abies alba) in West Germany during the early 1970s. By the early 1980s, declines were being reported in Britain (Binns et al., 1987), Norway (Tveite, 1987), Switzerland and Austria (Bucher, 1987), France (Bazire, 1987), Hungary (Jakucs, 1988), Czechoslovakia and East Germany (Blank et al., 1988). Hardwood forest decline in North America was first reported for yellow and white birch (Betula alleghaniensis, B. papyrifera) in the early 1930s in Nova Scotia (Hawboldt and Skolko, 1948), New Brunswick (Balch and Prebble, 1940), Quebec (Pomerleau, 1953) and Maine (Nash et al., 1951). Although declines of individual species in some areas have shown recent signs of recovery, e.g., silver fir in West Germany, many declines continue to worsen annually (Ulrich, 1988).

Sugar maple (Acer saccharum Marsh.) decline was first reported in Ontario in the Ottawa-Huron and Algoma extension forests (Nordin, 1954). Maple decline was subsequently noted in Wisconsin (Skilling, 1959), Massachusetts (Mader and Thompson, 1969), Michigan (Kessler, 1963), New York State (Hibben, 1964), New Hampshire (Lacasse and Rich, 1964) and Quebec (Pomerleau, 1953). Severe sugar maple decline has recently been reported in Quebec, specifically in the Appalachian region south of Quebec City. Aerial and field surveys have shown the decline in Quebec to be increasing both spatially and temporally (Gagnon et al., 1985). Recent declines in Ontario have been reported largely in the Sudbury, Parry Sound, Muskoka, Simcoe and Grey

Districts/Counties (McIlveen et al., 1986). The degree of reported damage to sugar maple stands in Ontario has been highly variable, ranging from light to severe.

Symptoms of sugar maple decline may include (McLaughlin et al., 1987):

- leaves often dwarfed and exhibiting interveinal necrosis;
- chlorosis and marginal leaf scorch;
- delayed spring bud flush;
- early leaf discolouration followed by premature leaf fall;
- progressive branch dieback;
- reductions in increment growth, slow tap hole closure;
- increased root mortality; and
- epicormic sprouting.

Various causes of forest decline have been hypothesized. There are presently more than 180 theories on the causes of forest decline, emphasizing the complexity of the phenomenon (Henrichsen, 1986). Some of the more likely contributing causes include:

- acid deposition/soil acidification (Cronan et al., 1980; Ulrich et al., 1980);
- pollutants, such as road salt (Guttay, 1976) and pesticides;
- stand dynamics (Bormann and Likens, 1979);
- diseases, such as Armillaria mellea root rot, wilts and cankers;
- insect infestation, especially the forest tent caterpillar (Malacosoma disstria);
- climatic conditions, such as drought (Bauch, 1983), frost, low winter temperatures and wind exposure;
- improper stand management, such as overcutting, overtapping and livestock grazing; and
- a combination of the above stresses (Manion, 1981).

1.2 Study Background

In the spring of 1984, maple syrup producers from the Muskoka region queried the Ontario Ministry of Agriculture and Food (OMAF) about an increase in dieback and mortality of sugar maple. The producers felt that continued sugar maple decline could jeopardize the local maple syrup industry and the health of hardwood forests regionally. Because air pollution was suggested as a possible cause for the decline, it was within the mandate of the Ontario Ministry of the Environment (MOE) to investigate the problem in Ontario. The three main studies specifically undertaken by the MOE to address the problem were:

- a site-specific Maple Decline Study;
- a Hardwood Decline Questionnaire; and
- a Hardwood Decline Survey.

1.2.1 The Site-Specific Maple Decline Study

A total of eleven permanent field sites were established in three areas of Ontario: seven were established in woodlots in the Muskoka region, two in the Peterborough area, one in Algonquin Park and one in a woodlot near Thunder Bay. The sites were chosen specifically to represent a gradient of decline. Detailed descriptions of the study are provided in McLaughlin et al. (1985). Woodlot owners provided detailed stand management histories for each site. Soil, foliage, twigs and roots were collected from a number of sugar maple trees in each plot exhibiting a gradient of decline symptoms. Increment cores were taken from a number of trees in each plot and examined for annual xylem growth patterns. Atmospheric acid deposition rates, forest management practices, the presence and history of disease and insects, site disturbance, tree age, site quality and weather records were also documented for each site.

The results from this study demonstrated that decline was not consistent with respect to topography, aspect or site (McLaughlin et al., 1985). Air pollution was concluded to be

a contributing factor to maple decline because of the elevated available aluminum concentrations detected in the soil of poorly-buffered sites, and because of the consistent trend towards reduced xylem growth in the last 30 years. Inciting factors included insect defoliation in 1975-1978; drought in 1976, 1977 and 1983; and tree age and improper site management (McLaughlin et al., 1987).

1.2.2 The Hardwood Decline Questionnaire

In 1985, with the cooperation and assistance of OMAF, the MOE distributed a questionnaire to 610 members of the Ontario Maple Syrup Producers Association. The questionnaire was intended to provide an immediate data base on the condition of Ontario's syrup-producing hardwood stands.

One third of the syrup producers felt that decline was a problem in their woodlot. Of the 33% reporting decline, 72% said it was getting worse, and 89% said they had not previously experienced a similar decline in their woodlot. The survey indicated that decline in maple syrup bushes was most common in the Georgian Bay, Algonquin Park and Parry Sound areas, and in the southwest counties.

1.2.3 The Hardwood Decline Survey

A Hardwood Decline Survey was initiated by the MOE in 1985 and involved:

- establishing a network of 110 permanent observation plots across the hardwood forest region of Ontario; and
- monitoring the crown condition of 100 marked trees in each of these plots, i.e., 11,000 trees in total.

Plots were established in the Great Lakes-St. Lawrence and Deciduous Forest Regions, as defined by Rowe (1972). The Haileybury Clay and Temagami Forest Sections were

excluded in the survey because suitable plots could not be located. Plot 95, located in the Ministry of Natural Resources' (MNR) Espanola District, was removed from the survey in 1990 because it was erroneously established on private property without the owner's permission. Thus, 109 plots were surveyed in 1990.

Plot Selection

A main objective of the hardwood survey was to establish a network of permanent plots which provided representative coverage of the geographic distribution of sugar maple (the target species) in Ontario using a stratified systematic sampling design. To this end, documents and maps were collected for the Province, including:

- 1:50,000 topographic maps;
- Forest Resources Inventory (FRI) maps; and
- 1:10,000 aerial photographs.

The Province was systematically divided into 100 km square blocks, and a minimum of one plot was established in each block. This was to ensure an even distribution of assessment coverage. Additional plots were then added in areas which had been previously identified as having either a low or high decline frequency. This was the stratified component of the design. The location of the survey plots is shown in Figure 1. The plots were chosen to a rigorous set of criteria, including:

- having greater than 50% sugar maple;
- belonging to a stand greater than 10 hectares in area;
- having a stand age between 75 and 150 years;
- having good access to accommodate re-evaluation;
- belonging to a relatively undisturbed stand in the last 20 years, with no scheduled cutting during the next 20 years;

Figure 1

Approximate location of survey plots

Ontario Hardwood Decline Survey

- being located more than 10 km from an urban area or point source of air pollution;
- being publicly owned (or an Agreement Forest, preferred); and
- being located at least 30 m from any woodlot edge.

Plot Installation

The survey plots were established in the following way (ESP, 1989):

- a pressure-treated 4" x 4" post was placed at the plot centre, and a plot identification tag was attached;
- the tree closest to the centre post (and located due north) was identified as tree Number 1;
- an engineer's transit was set up over the plot centre and aligned to this tree;
- one hundred trees of all species over 10 cm dbh were then numbered in a roughly circular area around the plot centre;
- the trees were numbered with an aluminum tag fixed at breast height, and the tree number was marked on the tree with paint (except where this conflicted with the land owner's wishes);
- a 30-metre buffer zone was established around each permanent plot by painting a ring of trees to discourage encroachment on the plots (Figure 2); and
- the plot was marked with a yellow MOE poster indicating that the stand was an MOE study plot.

All plots were located and mapped using standard MNR references, such as Township and stand number in northern Ontario, and township and compartment number in southern Ontario. Reference maps and directions for each plot also were prepared.

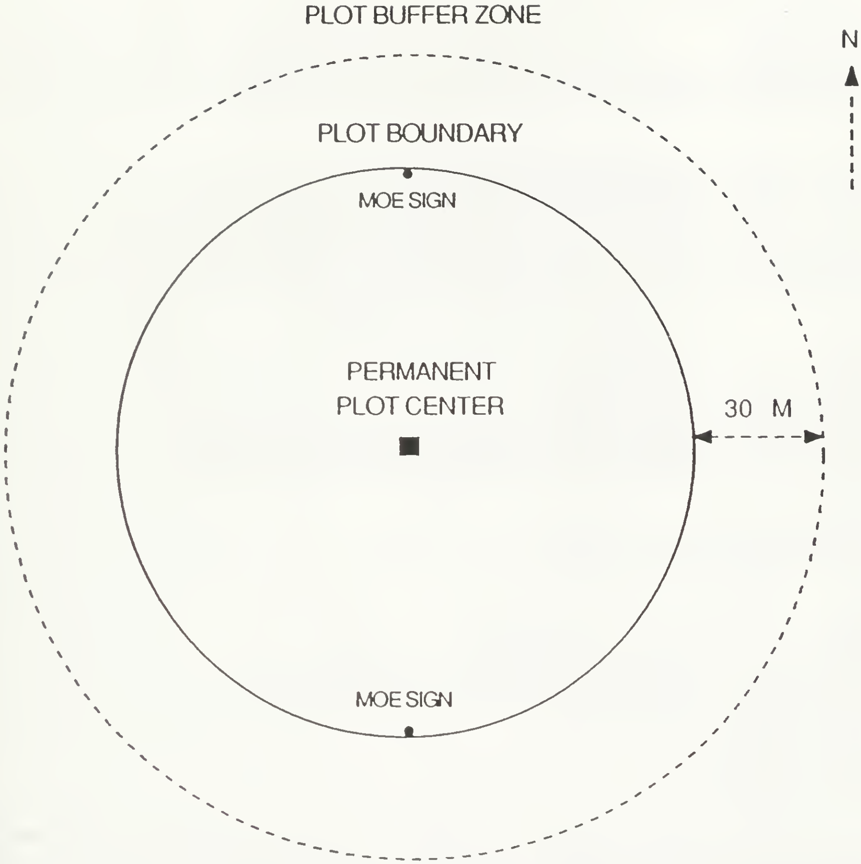


FIGURE 2: SCHEMATIC DESIGN OF HARDWOOD DECLINE PLOTS (SOURCE: ESP, 1989)

Plot Characteristics

Plot location summarizes are presented in Table 1 and include the following information for each plot:

- forest Region and Sector;
- Township with lot and concession (where available);
- MNR Administrative District;
- forest stand number (where available);
- NTS topographic map number;
- UTM coordinates; and
- applicable air photograph number (where available).

Other plot information includes:

- soils data (Table 2); and
- general stand characteristics (Table 3).

Tree Assessments

At each of the survey plots, 100 sample trees were evaluated for crown condition. Evaluations were made using the decline index (DI) technique developed by the MOE (McLaughlin et al., 1988). This technique involved a weighting of those symptoms most often observed in declining sugar maple in Ontario. These were:

- dieback of the fine branch structure,
- pale green or chlorotic foliage, and
- leaves which are distinctly undersized.

TABLE 1: SUMMARY OF GENERAL LOCATION INFORMATION FOR HARDWOOD DECLINE SURVEY PLOTS

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50,000 Map Number	UTM Coordinates	Air Photo Number
A-001	GLSL	4B	S. Hinsworth	N/A	N/A	North Bay	438	31E/14 South River	628200E 5093900N	N/A
A-002	GLSL	4B	Bethune	N/A	N/A	Bracebridge	243	31E/11 Burk's Falls	646200E 5048250N	N/A
A-003	GLSL	4B	Stewart	N/A	N/A	North Bay	81	31L/11 Temiscaming	620200E 5155050N	77-4623-100
A-004	GLSL	4B	Merrick	N/A	N/A	North Bay	83	31L/6 North Bay	616000E 5147250N	77-4620-65-188
A-005	GLSL	4B	Butt	N/A	N/A	Bracebridge	70	31E/11 Burk's Falls	650200E 5065500N	N/A
A-006	GLSL	2	Hawksbury	15	I	Cornwall	N/A	31G/9 Lachute	542300E 5045000N	78-4539-192-104
A-007	GLSL	2	Hawksbury	6	I	Cornwall	N/A	31G/9 Lachute	545500E 5044300N	78-4539-192-195
A-008	GLSL	2	Carlottenburgh	2	I	Cornwall	N/A	31G/2 & 31B/15 Cornwall	533400E 4993650N	78-4509-113-135
A-009	GLSL	4B	Ross	N/A	N/A	Pembroke	47	31F/10 Cobden	363250E 5060000N	76-4529-10-253
A-010	GLSL	2	Marlborough	24	X	Carleton Place	N/A	31G/4 Kemptville	425850E 4990300N	78-4506-109-61
A-011	GLSL	2	Lanark	6	IX	Carleton Place	N/A	31F/1 Carleton Place	397500E 4993100N	N/A
A-012	GLSL	2	Oxford	2	VII	Brockville	N/A	31B/13 Merrickville	448400E 4970250N	N/A
A-013	GLSL	10	Daumont	N/A	N/A	Sault Ste. Marie	289	41J/13 Ranger Lake	279850E 5185500N	81-4633-39-40
A-014	GLSL	2	Osnabruck	37	V	Cornwall	N/A	31G/3 Winchester	491400E 4985900N	78-4501-155-182
A-015	GLSL	10	Labonte	N/A	N/A	Wawa	216	41N/7 Agawa Bay	685250E 5246300N	N/A
A-016	GLSL	1	Carlyle	N/A	N/A	Sudbury	83	41I/3 Lake Panache	478200E 5100000N	N/A
A-017	GLSL	4D	Christie	N/A	N/A	Parry Sound	113	31E/5 Orrville	595000E 5275000N	77-4517-34-35
A-018	GLSL	4D	Monteith	N/A	N/A	Parry Sound	100	31E/5 Orrville	609500E 5325000N	77-4519-46-53
A-019	GLSL	1	Essa	27	VIII	Huronia	N/A	31D/5 Barrie	595975E 4907150N	78-4422-10-107
A-020	GLSL	1	Mulmur	2	I	Huronia	N/A	41A/1 Dundalk	568900E 4883400N	66-4403-102-43
A-021	GLSL	4B	Mulmur	12	III	Huronia	N/A	41A/1 Dundalk	565650E 4889100N	66-4403-102-44
A-022	GLSL	4B	Vespra	9	VI	Huronia	N/A	31D/5 Barrie	597500E 4922000N	N/A
A-023	GLSL	4B	Medonte	45	II	Huronia	N/A	31D/12 Elmvale	601650E 4935300N	N/A
A-024	GLSL	4B	Medonte	45	II	Huronia	N/A	31D/12 Elmvale	601450E 4935050N	N/A
A-025	GLSL	4B	Tiny	3	XVIII	Huronia	N/A	31D/13 Penetanguishene	580700E 4965350N	78-4459-5-220
A-026	GLSL	4E	Mason	N/A	N/A	Sudbury	10	41I/2 Delamere	538450E 5103000N	N/A
A-027	GLSL	1	Killarney	N/A	N/A	Sudbury	147	41I/13 Lake Panache	476325E 5099375N	N/A
A-028	GLSL	4E	Fairbank	N/A	N/A	Sudbury	99	41I/6 Coppercliff	467850E 5144750N	N/A
A-029	GLSL	4E	Trill	N/A	N/A	Sudbury	41	41I/12 Cartier	459250E 5150250N	N/A
A-030	GLSL	4E	Gough	N/A	N/A	Espanola	105	41I/5 Espanola	427250E 5129750N	N/A
A-031	GLSL	4E	Cadeau	N/A	N/A	Espanola	305	41J/8 Wiskey Lake	408070E 5130010N	N/A
A-032	GLSL	10	Scarle	N/A	N/A	Blind River	76	41J/6 Iron Bridge	343000E 5130750N	81-4613-02-59
A-033	GLSL	10	Scarle	N/A	N/A	Blind River	55	41J/6 Iron Bridge	341250E 5131000N	81-4613-02-59
A-034	GLSL	10	Gladstone	N/A	N/A	Blind River	92	41J/6 Iron Bridge	322750E 5131650N	81-4613-02-47
A-035	GLSL	10	Wells	N/A	N/A	Blind River	198	41J/6 Iron Bridge	312250E 5139250N	81-4616-03-37
A-036	GLSL	10	Mack	N/A	N/A	Blind River	59	41J/7 Elliot Lake	350900E 5132150N	81-4614-20-116
A-037	GLSL	10	Aberdeen	N/A	N/A	Sault Ste. Marie	30	41J/12 Echo Lake	279000E 5154600N	81-4622-36-37
A-038	GLSL	10	Hilton	N/A	N/A	Sault Ste. Marie	14	41J/4 St. Joseph Island	273250E 5124500N	81-4611-05-06
A-039	GLSL	10	Wishart	N/A	N/A	Sault Ste. Marie	10	41N/1 Batchewana	696500E 5213800N	81-4702-19-20
A-040	GLSL	10	Fisher	N/A	N/A	Sault Ste. Marie	24	41K/15 Pancake Bay	688900E 5204500N	81-4640-04-05

TABLE 1: SUMMARY OF GENERAL LOCATION INFORMATION FOR HARDWOOD DECLINE SURVEY PLOTS

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50,000 Map Number	UTM Coordinates	Air Photo Number
A-041	GLSL	1	Niagara-o-t-Lk	49	X	Niagara	99	30M/3 & 30M/6 Niagara	655700E 4779700N	78-4311-29-279
A-042	GLSL	1	Kinloss	23	VII	Wingham	1	40P/14 Wingham	468350E 4869800N	78-4369-215-68
A-043	DCD	1	Bertie	1	X	Niagara	170	30L/14 Welland	660500E 4752100N	78-4263-46-164
A-044	DCD	1	Town of Milton	14	III	Cambridge	N/A	30M/5 Hamilton	584650E 4811100N	N/A
A-045	DCD	1	Nassagaweya	6	V	Cambridge	11	30M/5 Burlington	583250E 4816450N	N/A
A-046	DCD	1	Norfolk	3	VIII	Simcoe	7	40I/10 Port Burwell	531825E 4725450N	78-4248-211-182
A-047	DCD	1	Malahide	4	V	Aylmer	7	40I/11 Port Stanley	498600E 4731400N	78-4251-203-134
A-048	DCD	1	Norwich	27	IX	Simcoe	2	40I/15 Tillsonburg	523600E 4749600N	78-4263-180-145
A-049	DCD	1	Blandford	5	I	Aylmer	N/A	40P/2 Woodstock	528600E 4777020N	78-4311-233-258
A-050	DCD	1	S.W. Oxford	7	III	Aylmer	N/A	40P/2 Woodstock	518100E 4667700N	78-4305-184-207
A-051	DCD	1	Bosanquet	48	VI	Chatham	2	40P/4 Parkhill	424700E 4781200N	78-4328-42-181
A-052	DCD	1	Essa	27	VIII	Huronia	N/A	31D/5 Barrie	596800E 4907500N	78-4422-10-106
A-053	DCD	1	Oneida	N/A	V	Niagara	64	30M/4 Hamilton/Grimsby	588450E 4762375N	78-4302-117-31
A-054	GLSL	4C	R. Young & Esc.	21	IX	Brockville	N/A	31B/12 Brockville	421850E 4940950N	N/A
A-055	DCD	1	Lincoln	14	VII	Niagara	112	30M/3 & 30M/6 Niagara	625150E 4775750N	78-4359-29-360
A-056	DCD	1	Wilmot	N/A	NBR	Cambridge	N/A	40P/7 Stratford	530100E 4804700N	N/A
A-057	DCD	1	Town Whitchurch	22	V	Maple	N/A	31D/3 Newmarket	632000E 4771500N	N/A
A-058	DCD	1	Lincoln	21	N/A	Niagara	147	30M/3 & 30M/6 Niagara	622350E 4774000N	78-4309-29-350
A-059	DCD	1	Hamilton	5	I	Lindsay	N/A	30M/16 Port Hope	731500E 4875000N	78-4369-50-152
A-060	GLSL	1	Clarke	21	VIII	Lindsay	N/A	31D/2 Scugog	691800E 4880750N	N/A
A-061	GLSL	4C	Cardiff	N/A	N/A	Bancroft	609	31D/16 Gooderham	731675E 4978250N	77-4438-16-14
A-062	GLSL	4C	McClure	5	XIII	Bancroft	101	31E/8 Whitney	733250E 5023650N	77-4514-53-208
A-063	GLSL	4D	Cavendish	N/A	N/A	Minden	394	31D/9 Burleigh Falls	714000E 4956950N	77-4431-13-7
A-064	GLSL	4D	Glamorgen	18	XIV	Minden	112	31D/16 Gooderham	700650E 4982200N	77-4440-32-121
A-065	GLSL	4D	Stanhope	17	VII	Minden	209	31E/2 Haliburton	679100E 4997300N	77-4507-36-233
A-066	GLSL	4D	Hindon	29	X	Minden	153	31E/2 Haliburton	659800E 4991900N	77-4502-34-98
A-067	GLSL	4D	Sherbourne	N/A	N/A	Minden	162	31E/2 Haliburton	666600E 5022000N	77-4505-36-177
A-068	DCD	1	Warwick	29	II	Chatham	N/A	40P/4 Parkhill	434650E 4763020N	78-4302-251-113
A-069	DCD	1	Zare	31	VII	Chatham	N/A	40I/12 Bothwell	426150E 4731550N	78-4253-250-98
A-070	DCD	1	East Williams	3	XX	Aylmer	N/A	40P/4 Parkhill	447650E 4778650N	78-4312-234-57
A-071	GLSL	4D	Georgian Bay	3	VIII	Parry Sound	Ind. Res.	31E/4 Lake Joseph	598550E 4986100N	77-4502-34-56
A-072	GLSL	1	Bexley	N/A	Long Point	Lindsay	N/A	31D/10 Fenelon Falls	669700E 4936250N	78-4439-17-492
A-073	GLSL	1	Asphodel	9	III	Lindsay	N/A	31D/8 Peterborough	736000E 4911600N	78-4420-8-368
A-074	GLSL	1	Scugog	14	XI	Lindsay	N/A	31D/3 Newmarket	659400E 4891700N	78-4412-67-202
A-075	DCD	1	King	20	VI	Maple	N/A	30M/13 Bolton	611800E 4869000N	N/A
A-076	GLSL	1	Colburne	9	II	Wingham	Morris Tr.	40P/12 Goderich	448450E 4840550N	78-4351-268-70
A-077	GLSL	1	Morris	26	VIII	Wingham	N/A	40P/11 Seaforth	476150E 4839900N	78-4350-268-127
A-078	GLSL	1	Culross	25	VI	Wingham	N/A	40P/14 Wingham	473200E 4870150N	N/A
A-079	GLSL	4C	Anglesea	N/A	N/A	Tweed	217	31C/14 Mazinaw Lake	321800E 4974500N	78-4463-78-24
A-080	GLSL	4C	Ellingham	N/A	N/A	Tweed	265	31F/3 Denbigh	315400E 4986300N	78-4501-154-168

TABLE 1: SUMMARY OF GENERAL LOCATION INFORMATION FOR HARDWOOD DECLINE SURVEY PLOTS

Plot Number	Forest Region	Forest Sector	Township	Lot	Concession	MNR District	FRI Stand	NTS 1:50,000 Map Number	UTM Coordinates	Air Photo Number
A-081	GLSL	4C	South Canonto	N/A	N/A	Tweed	644	31F/2 Clyde Forks	352350E 4988850N	78-4503-154-186
A-082	GLSL	2	Hallowell	N/A	N/A	Napanee	P.P. Res.	30N/14 Wellington	318500E 4863500N	78-4363-12-200
A-083	GLSL	2	Bedford	N/A	N/A	Napanee	P.P. Res.	31C/10 Tichborne	379050E 4936100N	N/A
A-084	GLSL	1	Collingwood	7	X	Owen Sound	492	41A/8 Collingwood	544800E 4918100N	N/A
A-085	GLSL	1	St. Vincent	27	XII	Owen Sound	1	41A/10 Owen Sound	521700E 4943300N	N/A
A-086	GLSL	2	South Burgess	5	II	Brockville	269	31C/16 Perth	406700E 4958300N	N/A
A-087	GLSL	1	Saugeen	11	IV	Owen Sound	N/A	41A/6 Chesley	475050E 4911000N	N/A
A-088	GLSL	1	Saugeen	36	IX	Owen Sound	235	41A/6 Chesley	463000E 4916700N	N/A
A-089	GLSL	4D	McKenzie	29	VII	Parry Sound	N/A	41H/9 Pointe au Baril	574550E 5062650N	77-4530-86-34
A-090	GLSL	4D	Ferrie	25	VII	Parry Sound	222	31E/13 Golden Valley	590850E 5068350N	77-4532-43-142
A-091	GLSL	4D	Chapman	N/A	N/A	Parry Sound	247	31E/12 Magnetawan	606050E 5057850N	77-4528-86-318
A-092	GLSL	4D	Lount	25	XI	Parry Sound	4	31E/13 Golden Valley	600550E 5078850N	77-4536-57-100
A-093	GLSL	4E	Sandfield	26	X	Espanola	342	41G/16 Kagawong	414700E 5068200N	73-4532-9-229
A-094	GLSL	4E	Allan	19	X	Espanola	246	41G/16 Kagawong	393900E 5084650N	73-4538-2-120
A-095	GLSL	4E	Robinson	28	XI	Espanola	208	41G/15 Silver Water	353300E 5083400N	73-4537-8-50
A-096	GLSL	4B	Finlakson	N/A	N/A	Algonquin Park	332	31E/7 Kawagama Lake	670150E 5033900N	N/A
A-097	GLSL	4B	Peck	N/A	N/A	Algonquin Park	272	31E/10 Tom Thomson Lake	681400E 5045600N	N/A
A-098	GLSL	4B	Sproule	N/A	N/A	Algonquin Park	821	31E/9 Opeongo Lake	710650E 5051700N	N/A
A-099	GLSL	4B	Dickson	N/A	N/A	Algonquin Park	N/A	31E/16 Lake Lavielle	707400E 5077300N	N/A
A-100	GLSL	4C	Jones	N/A	N/A	Pembroke	228	31F/5 Barry's Bay	281200E 5036650N	76-4520-7-118
A-101	GLSL	4E	Nipissing	N/A	N/A	North Bay	N/A	31L/4 Nipissing	610700E 5105550N	77-4604-81-122
A-102	GLSL	1	St. Edmunds	20	VI	Owen Sound	542	41H/3 Dyer's Bay	462170E 5007150N	N/A
A-103	GLSL	1	Eastnor	N/A	XI	Owen Sound	N/A	41A/14 Cape Crocker	488000E 4974000N	N/A
A-104	GLSL	4E	Papineak	22	XII	North Bay	N/A	31L/7 Mattawa	673500E 5127500N	77-4608-69-146
A-105	GLSL	1	Keppel	N/A	XI	Owen Sound	N/A	41A/14 Cape Crocker	492450E 4962400N	N/A
A-106	GLSL	4E	Truman	N/A	N/A	Espanola	Unsurveyed	41I/4 Whitefish Falls	456200E 5115650N	N/A
A-107	GLSL	4E	McKinnon	N/A	N/A	Espanola	Unsurveyed	41I/4 Whitefish Falls	430550E 5109450N	N/A
A-108	GLSL	11	Blake	N/A	N/A	Thunder Bay	N/A	52A/6 Thunder Bay	322650E 5349500N	N/A
A-109	GLSL	11	Blake	N/A	N/A	Thunder Bay	N/A	52A/6 Thunder Bay	321850E 5350600N	N/A
A-110	GLSL	11	Pardee	N/A	N/A	Thunder Bay	N/A	52A/4 Pidgeon River	307400E 5326300N	N/A

Source: ESP (1989)

"N/A" indicates no data available.

TABLE 2: SUMMARY OF FIELD SOILS DATA FOR THE HARDWOOD DECLINE PLOTS

Plot No.[1]	Depth to Bedrock[2] (cm)	Depth to Carb.[3] (cm)	Internal Drainage[4]	Moisture Regime[5]	A Horizon Texture[6]	A Horizon Thickness (cm)	B Horizon Texture	B Horizon Thickness (cm)	C Horizon Thickness (cm)	Slope Percent	Slope Type[7]	Position on Slope	Gravel (Depth)	Rockiness	Stoniness
A-001	200	200	Well	1	SL	0	SL	0	Rock	0	N/A	Upper	None	Very	Moderate
A-002	80	200	Well	2	SL	10	SL	30	SL	0	N/A	Upper	None	Slight	Slight
A-003	200	200	Well	2	L	8	L	39	L	0	N/A	Upper	80-120	Slight	Slight
A-004	51	200	Well	2	S	11	SL	27	SL	0	N/A	Upper	None	Moderate	Moderate
A-005	35	200	Well	2	L	13	L	22	N/A	0	N/A	Upper	None	Non	Non
A-006	65	200	Well	2	FSL	7	FSL	23	FSL	N/A	N/A	Upper	None	Non	Non
A-007	30	200	Well	2	FSL	5	FSL	21	N/A	N/A	N/A	Flat	0-30	Non	Moderate
A-008	30	200	Well	2	CL	7	CL	11	CL	N/A	N/A	Flat	None	Non	Non
A-009	200	200	Rapid	1	LFS	1	LS	9	FS	0	N/A	Flat	30-120	Moderate	Slight
A-010	200	200	Rapid	1	LS	3	LS	12	LS	0	N/A	Flat	None	Moderate	Moderate
A-011	200	200	Well	2	SL	9	SL	9	SL	0	N/A	Crest	33-120	Non	Moderate
A-012	53	200	Rapid	1	LFS	10	LFS	10	LFS	0	N/A	Middle	None	Non	Non
A-013	200	200	Rapid	1	LS	5	LS	25	LS	0	N/A	Flat	None	Non	Slight
A-014	55	200	Well	2	SL	8	SL	35	SL	N/A	N/A	Flat	0-55	Very	Moderate
A-015	30	300	Well	2	CL	6	L	24	N/A	0	N/A	Crest	None	Non	Non
A-016	200	200	Well	2	SIL	3	SIL	27	SIL	N/A	N/A	Lower	None	Slight	Slight
A-017	55	200	Well	2	FSL	14	FSL	27	FSL	N/A	N/A	Upper	0-55	Moderate	Non
A-018	55	200	Well	2	FSL	13	FSL	25	FSL	N/A	N/A	Flat	0-55	Slight	Non
A-019	75	200	Rapid	1	LFS	5	LFS	42	LFS	N/A	N/A	Flat	None	Non	Non
A-020	35	200	Well	2	FSL	15	L	10	L	N/A	N/A	Middle	None	Slight	Slight
A-021	40	200	Well	2	L	9	L	15	L	0	N/A	Middle	None	Very	Moderate
A-022	50	200	Well	2	MSL	10	MS	40	N/A	0	N/A	Middle	None	Slight	Slight
A-023	200	200	Well	2	MS	4	N/A	12	N/A	0	N/A	Flat	None	Non	Non
A-024	60	200	Well	2	MS	15	MS	45	N/A	0	N/A	Lower	None	Non	Non
A-025	35	200	Well	2	MSL	10	MSL	25	N/A	0	N/A	Middle	None	Slight	Slight
A-026	200	200	Mod. Well	2	SIC	3	SIC	17	SIC	0	N/A	Flat	None	Non	Non
A-027	200	200	Well	2	SI	5	SI	40	SI	0	N/A	Flat	None	Non	Non
A-028	20	200	Well	2	SI	3	SI	12	N/A	0	N/A	Middle	None	Moderate	Moderate
A-029	40	200	Well	2	VFSL	3	VFSL	27	VFSL	0	N/A	Middle	None	Exceed	Exceed
A-030	200	200	Mod. Well	3	SIL	4	SIFS	26	CL	0	N/A	Lower	None	Non	Non
A-031	20	200	Well	2	LFS	7	LFS	13	N/A	0	N/A	Crest	None	Exceed	Non
A-032	10	200	Well	2	LMS	8	LMS	1	N/A	0	N/A	Middle	None	Slight	Slight
A-033	20	200	Rapid	1	LMS	6	LFS	14	N/A	0	N/A	Middle	None	Slight	Non
A-034	55	200	Well	2	FLS	3	LFS	52	N/A	0	N/A	Middle	None	Moderate	Moderate
A-035	70	200	Well	2	VFSL	5	VFSL	45	L	0	N/A	Upper	None	Slight	Slight
A-036	30	200	Rapid	0	LNS	7	LMS	23	N/A	0	N/A	Flat	None	Non	Non
A-037	50	200	Rapid	1	FLS	6	LFS	21	FLS	0	N/A	Crest	None	Slight	Slight
A-038	30	200	Well	2	MS	15	MS	15	N/A	0	N/A	Flat	None	Non	Non
A-039	40	200	Well	2	VFSL	10	L	30	N/A	0	N/A	Middle	None	Slight	Slight
A-040	70	200	Mod. Well	3	FSL	6	FSL	35	LS	0	N/A	Flat	None	Slight	Slight

TABLE 2: SUMMARY OF FIELD SOILS DATA FOR THE HARDWOOD DECLINE PLOTS

Plot No.[1]	Depth to Bedrock[2] (cm)	Depth to Carb.[3] (cm)	Internal Drainage[4]	Moisture Regime[5]	A Horizon Texture[6]	A Horizon Thickness (cm)	B Horizon Texture	B Horizon Thickness (cm)	C Horizon Thickness (cm)	Slope Percent	Slope Type[7]	Position on Slope	Gravel (Depth)	Rockiness	Stoniness
A-041	200	5	Imperfect	6	SICL	13	SICL	23	SICL	0	S	Middle	0-120	Exceed	Exceed
A-042	75	200	Mod. Well	4	L	8	L	68	SIL	50	N/A	Flat	None	Non	Non
A-043	200	0	Well	2	GL	8	GL	32	N/A	0	N/A	Flat	0-120	Exceed	Exceed
A-044	200	200	Well	2	L	20	FSL	50	FSL	0	S	Flat	0-120	Excess	Excess
A-045	200	200	Well	2	L	20	CL	40	N/A	0	S	Middle	0-65	Excess	Excess
A-046	200	80	Mod. Well	3	L	30	SIL	50	SIL	0	S	Flat	None	Non	Non
A-047	200	200	Well	2	FSL	20	FSL	80	FSL	30	N/A	N/A	None	Non	Non
A-048	200	200	Imperfect	5	SIL	25	SIVFS	42	N/A	0	S	Middle	None	Non	Non
A-049	200	85	Imperfect	4	L	14	FSL	70	FSL	5	C	Toe	None	Non	Non
A-050	200	87	Mod. Well	3	CL	12	SIL	75	CL	0	S	Flat	None	Non	Non
A-051	200	200	Well	2	SL	14	SL	58	SCL	0	S	Flat	None	Non	Non
A-052	200	200	Well	2	LVFS	8	LVFS	20	VFS	0	C	Crest	None	Non	Non
A-053	200	38	Mod. Well	2	CL	20	C	18	SIC	0	S	Crest	None	Non	Non
A-054	65	8	Well	2	FSL	7	L	58	N/A	1	S	Middle	0	Moderate	Moderate
A-055	200	75	Well	2	SIL	20	SICL	55	SICL	0	N/A	Flat	None	Non	Non
A-056	200	200	Mod. Well	4	FSL	25	FSL	50	LFS	0	S	Flat	None	Non	Slight
A-057	200	200	Well	2	SIFS	5	VFSL	12	VFSL	30	S	Middle	None	Non	Non
A-058	100	200	Well	2	L	25	L	40	L	3	C	Lower	0	Exceed	Moderate
A-059	90	42	Well	2	L	10	FSL	32	LFS	0	S	Upper	10	Slight	Slight
A-060	200	20	Well	2	VFSL	20	FSL	25	FS	3	S	Middle	20-45	Slight	Slight
A-061	80	200	Well	3	FSL	8	FSL	50	CL	5	C	Middle	None	Moderate	Moderate
A-062	60	200	Rapid	0	LS	8	LFS	50	N/A	50	S	Middle	None	Non	Moderate
A-063	50	200	Well	2	N/A	12	FSL	28	VFSL	5	C	Depres.	None	Non	Slight
A-064	90	200	Mod. Well	3	LVFS	15	SIVFS	40	SIFS	5	C	Upper	None	Slight	Slight
A-065	68	200	Well	1	LFS	10	LFS	55	N/A	20	C	Upper	0-15	Slight	Slight
A-066	60	200	Well	2	LVFS	20	LVFS	40	N/A	20	C	Upper	None	Moderate	Moderate
A-067	200	200	Well	2	VFSL	15	VFSL	55	SIL	0	C	Lower	33-120	Moderate	Slight
A-068	200	50	Imperfect	5	CL	12	CL	38	CL	0	S	Flat	None	Non	Non
A-069	200	85	Well	2	LVFS	10	LVFS	90	N/A	0	S	Flat	None	Non	Non
A-070	200	45	Rapid	0	LMS	15	LMS	40	LMS	0	S	Crest	0-120	Slight	Moderate
A-071	200	42	Mod. Well	4	VFS	6	VFS	42	N/A	20	S	Middle	0-23	Non	Very
A-072	200	10	Well	2	L	10	L	20	FSL	0	S	Lower	None	Slight	Slight
A-073	200	200	Well	2	VFSL	20	LVFS	40	LVFS	0	N/A	N/A	None	Non	Non
A-074	80	65	Well	2	L	18	L	22	CL	3	S	Upper	65-80	Slight	Slight
A-075	200	110	Well	1	SIVFS	12	SIVFS	80	SIVFS	30	C	Upper	None	Slight	Non
A-076	200	20	Imperfect	5	SICL	20	SIC	30	SIC	60	N/A	Lower	None	Non	Slight
A-077	200	25	N/A	2	L	8	VFSL	20	FS	0	C	Lower	25-120	Slight	Slight
A-078	200	200	Rapid	0	LMS	10	MS	35	MS	40	C	Upper	15-120	Non	Non
A-079	70	200	Well	2	VFSL	8	VFSL	15	VFSL	40	S	Upper	0-70	Non	Moderate
A-080	90	200	Well	2	LVFS	6	LVFS	70	N/A	25	C	Upper	25-35	Moderate	Moderate

TABLE 2: SUMMARY OF FIELD SOILS DATA FOR THE HARDWOOD DECLINE PLOTS

Plot No.[1]	Depth to Bedrock[2] (cm)	Depth to Carb.[3] (cm)	Internal Drainage[4]	Moisture Regime[5]	A Horizon Texture[6]	A Horizon Thickness (cm)	B Horizon Texture	B Horizon Thickness (cm)	C Horizon Thickness (cm)	Slope Percent	Slope Type[7]	Position on Slope	Gravel (Depth)	Rockiness	Stoniness
A-081	110	200	Well	1	LFS	40	LFS	65	N/A	20	S	Middle	None	Slight	Slight
A-082	50	20	Well	2	SIC	10	SIC	40	N/A	0	N/A	Flat	0-20	Non	Non
A-083	70	200	Mod. Well	2	CL	8	SIC	52	N/A	35	S	Middle	0-60	Moderate	Moderate
A-084	64	15	Well	2	L	8	L	52	N/A	40	S	Middle	0-61	Moderate	Moderate
A-085	40	200	Mod. Well	2	SIC	7	SIC	33	N/A	5	S	Lower	None	Very	Non
A-086	45	200	Well	2	VFSL	10	VFSL	35	N/A	10	S	Middle	0-45	Moderate	Moderate
A-087	200	200	Mod. Well	3	FSL	18	VFS	58	VFS	0	N/A	N/A	None	Slight	Slight
A-088	200	40	Well	2	LVFS	24	VFSL	20	LVFS	0	S	N/A	0-90	Non	Non
A-089	70	200	Well	2	SIL	10	SIL	30	SIL	5	C	Middle	35-70	Non	Slight
A-090	200	200	Imperfect	4	SIL	11	SIFS	29	FSL	5	C	N/A	None	Slight	Slight
A-091	200	200	Well	2	SIL	15	SIL	22	VFSL	5	C	Middle	10-80	Moderate	Moderate
A-092	55	200	Well	1	SIFS	15	SIVFS	40	N/A	20	S	Upper	0-55	Slight	Slight
A-093	25	200	Rapid	1	LFS	20	LFS	5	N/A	0	N/A	N/A	0-25	Slight	Slight
A-094	200	200	Well	2	SIFS	13	SIFS	35	N/A	0	N/A	N/A	48-120	Moderate	Moderate
A-095	50	200	Well	1	VFS	15	SIFS	30	N/A	0	N/A	N/A	0-50	Very	Very
A-096	200	200	Well	2	L	10	LVFS	50	LFS	10	S	Middle	63-100	Slight	Non
A-097	100	200	Well	2	L	15	VFSL	45	LFS	10	S	Middle	60-100	Non	Non
A-098	200	200	Well	2	FSL	10	FSL	28	LVFS	12	S	Upper	0-83	Non	Non
A-099	70	200	N/A	2	VFSL	15	SIVFS	35	SIVFS	0	S	Crest	9-70	Very	Very
A-100	52	200	Well	2	FSL	8	LVFS	49	N/A	0	C	Middle	0-52	Very	Very
A-101	80	200	Well	2	L	8	SIL	47	LMS	2	C	Upper	0-80	Moderate	Moderate
A-102	200	200	Well	2	SL	15	SIFL	25	N/A	0	C	Flat	0-55	Moderate	Slight
A-103	65	200	Well	2	SIL	7	SIL	43	SICL	5	C	Crest	40-65	Exceed	Exceed
A-104	60	200	Mod. Well	3	VFSL	5	L	30	VFSL	1	S	Middle	25-60	Moderate	Moderate
A-105	200	200	Well	2	SICL	10	SIL	36	SI	0	C	Flat	None	Moderate	Moderate
A-106	50	200	Well	1	LFS	10	LFS	35	N/A	0	N/A	Flat	0-50	Non	Non
A-107	200	200	Well	2	SIMS	5	SINS	28	N/A	20	S	Upper	None	Non	Non
A-108	200	200	Mod. Well	4	L	10	L	40	L	5	S	Middle	0-120	Non	Non
A-109	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A-110	200	200	Imperfect	5	FSL	10	SCL	40	N/A	20	S	Middle	0-120	Exceed	Exceed

Source: ESP (1989)

[1] Plot locations are as shown in Figure 1.

[2] Three classes:

	0-40 cm (very shallow)
	41-100 cm (shallow)
	GT 100 cm (deep)

A value of 200 indicates no bedrock was encountered.

[3] Three classes:

	0-50 cm (strongly limey)
	51-100 cm (weakly limey)
	GT 100 cm (no carbonates encountered)

A value of 200 indicates no free carbonates were encountered.

[4] four drainage classes:

"Well"	=	well and moderately well-drained
"Rapid"	=	very rapid and rapid drained
"Imperfect"	=	imperfectly drained
"Poor"	=	poorly-drained

[5] Ten moisture classes:

0	=	moderately dry
1	=	moderately fresh
2	=	fresh
3	=	very fresh
4	=	moderately moist
5	=	moist
6	=	very moist
7	=	moderately wet
8	=	wet
9	=	very wet

[6] Eleven texture classes:

SL	=	sandy loam
L	=	loam
S	=	sand
FSL	=	fine sandy loam
CL	=	clayey loam
LFS	=	loamy fine sand
LS	=	loamy sand
SIL	=	silty loam
MS	=	medium sand
SIC	=	silty clay
SI	=	silt

[7] "S" indicates simple slopes, while "C" indicates complex topography.

"N/A" indicates no data available.

TABLE 3: SUMMARY OF GENERAL FOREST STAND CHARACTERISTICS OF THE HARDWOOD DECLINE STUDY PLOTS (at the time of establishment - 1986)

Plot No.[1]	Mean dbh (cm)	Mean Tree Height (m)	Mean Breast Height Age	Total Basal Area (m^2/ha)	Mean % Crown Closure
A-001	16.8	15.6	N/A	20.0	75
A-002	21.0	20.2	93	34.0	75
A-003	21.1	19.9	N/A	28.0	75
A-004	21.8	17.0	N/A	20.0	65
A-005	25.9	18.9	113	26.0	N/A
A-006	32.9	25.3	107	23.2	N/A
A-007	35.7	26.8	103	25.2	85
A-008	22.6	19.7	73	22.0	80
A-009	22.3	19.1	77	14.0	50
A-010	22.7	18.6	82	20.4	N/A
A-011	20.8	14.5	N/A	24.4	80
A-012	22.6	19.9	93	18.8	65
A-013	22.4	16.3	78	18.8	50
A-014	22.0	19.7	81	19.6	85
A-015	23.1	14.6	N/A	18.8	50
A-016	22.4	18.1	93	21.6	90
A-017	17.7	13.2	76	18.8	N/A
A-018	26.2	17.8	82	14.8	N/A
A-019	36.7	27.8	102	26.0	75
A-020	26.8	21.0	85	24.8	90
A-021	26.5	21.2	86	26.4	90
A-022	21.0	19.5	95	25.6	99
A-023	20.7	18.9	102	24.0	95
A-024	25.0	18.7	95	24.0	90
A-025	21.4	20.0	N/A	19.6	99
A-026	20.8	18.9	86	22.0	75
A-027	23.2	18.8	117	23.6	N/A
A-028	21.0	18.2	82	24.0	85
A-029	20.1	18.3	82	24.0	70
A-030	26.3	21.8	127	19.6	70
A-031	17.8	16.0	N/A	18.8	85
A-032	23.2	16.8	87	23.2	80
A-033	24.4	18.1	N/A	25.6	85
A-034	24.6	18.7	103	22.0	90
A-035	18.9	14.8	73	19.2	70
A-036	29.5	20.0	N/A	26.8	85
A-037	27.3	22.3	N/A	23.6	65
A-038	20.6	18.2	N/A	19.6	N/A
A-039	22.1	15.4	77	22.4	60
A-040	27.3	19.4	76	22.4	90

TABLE 3: (Cont'd) SUMMARY OF GENERAL FOREST STAND CHARACTERISTICS OF THE HARDWOOD DECLINE STUDY PLOTS (at the time of establishment - 1986)

Plot No.[1]	Mean dbh (cm)	Mean Tree Height (m)	Mean Breast Height Age	Total Basal Area (m^2/ha)	Mean % Crown Closure
A-041	27.3	19.6	63	14.8	85
A-042	35.1	29.7	102	28.8	85
A-043	29.2	25.8	60	22.8	90
A-044	28.8	22.9	85	21.6	80
A-045	26.4	23.8	77	23.2	80
A-046	30.3	25.6	69	24.0	85
A-047	30.2	25.8	65	22.8	85
A-048	27.5	25.6	96	27.6	75
A-049	26.0	28.6	71	24.4	85
A-050	31.9	29.5	80	25.6	80
A-051	26.8	25.2	74	23.2	70
A-052	23.5	24.1	79	30.0	75
A-053	21.3	20.8	63	20.8	90
A-054	24.9	21.1	100	21.2	60
A-055	23.4	24.6	60	26.0	90
A-056	26.2	27.2	67	26.4	80
A-057	26.8	19.8	89	22.0	95
A-058	25.2	21.1	84	28.0	80
A-059	23.2	19.6	63	16.0	60
A-060	24.9	21.3	76	16.0	70
A-061	25.0	25.5	N/A	21.2	65
A-062	21.3	21.7	67	26.4	95
A-063	23.5	21.1	90	24.0	65
A-064	28.0	23.3	N/A	23.2	60
A-065	19.9	17.2	71	26.4	75
A-066	25.9	22.3	N/A	15.6	50
A-067	28.8	21.6	87	24.8	65
A-068	22.2	22.5	63	23.6	85
A-069	57.7	23.1	60	25.2	70
A-070	26.4	24.7	81	28.4	80
A-071	23.8	19.5	117	32.4	75
A-072	26.9	21.9	N/A	21.2	65
A-073	30.6	24.8	96	24.8	70
A-074	26.8	24.7	79	16.8	65
A-075	26.8	24.8	108	24.4	80
A-076	26.5	26.9	61	34.0	80
A-077	19.8	19.8	75	30.4	90
A-078	22.1	22.2	68	28.8	80
A-079	24.9	21.3	97	26.8	80
A-080	23.0	17.6	94	21.6	60

TABLE 3: (Cont'd) SUMMARY OF GENERAL FOREST STAND CHARACTERISTICS OF THE HARDWOOD DECLINE STUDY PLOTS
(at the time of establishment - 1986)

Plot No.[1]	Mean dbh (cm)	Mean Tree Height (m)	Mean Breast Height Age	Total Basal Area (m^2/ha)	Mean % Crown Closure
A-081	20.2	19.0	104	30.0	70
A-082	25.1	21.3	114	26.4	75
A-083	22.5	20.0	85	18.0	60
A-084	25.7	21.3	100	26.4	85
A-085	22.2	22.3	63	26.0	70
A-086	24.6	20.8	84	20.0	75
A-087	35.4	28.0	77	29.2	65
A-088	20.2	21.5	73	33.2	85
A-089	19.2	16.9	74	22.8	75
A-090	27.0	20.0	95	25.6	60
A-091	22.6	18.6	68	24.0	65
A-092	25.1	19.9	102	26.4	75
A-093	21.3	18.2	67	25.6	60
A-094	21.0	18.3	77	24.4	60
A-095	26.2	20.2	122	22.0	50
A-096	30.4	21.0	93	24.4	75
A-097	25.0	20.8	88	28.0	80
A-098	20.2	20.6	60	29.6	75
A-099	25.5	20.3	75	28.8	75
A-100	24.0	19.8	83	30.4	80
A-101	24.9	23.0	74	25.2	70
A-102	20.3	21.2	75	33.6	85
A-103	23.4	18.1	87	29.2	80
A-104	24.6	19.7	82	26.0	75
A-105	21.9	18.7	70	31.2	85
A-106	28.0	20.2	133	26.8	75
A-107	18.9	17.9	70	20.4	70
A-108	20.7	16.9	78	22.4	80
A-109	27.8	18.9	N/A	28.4	65
A-110	19.2	16.8	N/A	25.2	50

Source: ESP (1989)

[1] Plot locations are as shown in Figure 1.

N/A = No data available.

These three parameters were individually assessed to the nearest 10% and then combined in the weighted formula to yield an numerical DI value ranging from 0 (a healthy tree with no symptoms) to 100 (a dead tree).

The DI formula is:

$$DI = DB + (A \times UL) + (A \times ST) + (A \times SL/2)$$

where:
- DI = decline index;
- DB = percent dead branches;
- A = (100 - DB)/400;
- UL = percent undersized leaves;
- ST = percent strong chlorosis; and
- SL = percent slight chlorosis.

To aid in the assessment of each of the above characteristics, laminated field assessment templates were prepared, illustrating a series of tree crown silhouettes in 10% decline gradients. On the reverse side of the templates were three series of colour chips. Each of the three series contains six chips chosen to illustrate a range of foliar colour encountered in sugar maples in Ontario. One series represents normal green foliage, the second represents pale green or slightly chlorotic foliage, and the third illustrates the colour range considered to be strongly chlorotic.

Using these templates, two evaluators trained in the recognition of characteristics decline symptoms in Ontario, subjectively estimated the amount of crown and branch dieback, slight and strong chlorosis and undersized leaves for each tree. This information was recorded on a decline assessment form, (e.g., Figure 3) and later transcribed to a spreadsheet file where the DI is calculated.

FIGURE 3:

beak

TREE CONDITION ASSESSMENT FORM

DATE ______ ASSESSOR ______

SITE No. ______ WEATHER ______

LOCATION ______

1-Broken Stem
2-Wound
3-Crack or Seam
4-Tap Holes Healed
5-Tap Holes Total
6-Other Holes
7-Fungal Structures
8-Cankers
9-Insect Injury
10-Other Wounds
11-Sugar Maple Borer Galleries
12-Swelling
13-Sprout Location
14-Sprout Abundance
15-Bark Sloughing
16-Nails in Tree
17-Other ______

TREE	SPECIES CODE	%DEAD BRANCHES		% SLIGHT CHLOROSIS	% STRONG CHLOROSIS	% EARLY FALL COLOUR	% NECROSIS	% SMALL LEAVES	CROWN CLASS RATIO	% DEFOLIATION	DBH (cm)	HEIGHT (m)	HEIGHT TO LOWEST BRANCH (m)	CROWN WIDTH			ADDITIONAL OBSERVATIONS															
		LARGE	TWIGS											N	S		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

The DI technique has been shown to be reproducible (McLaughlin et al., 1988) and was used by Ecological Services for Planning (ESP) for 1986 and 1987 Hardwood Decline Surveys (McIlveen et al., 1989 and ESP, 1989). The results from these surveys showed that decline problems in Ontario were concentrated in the southwest and northcentral regions of Ontario (McIlveen et al., 1989 and ESP, 1989). Increases in DIs (deterioration in tree condition) during the 1986 and 1987 growing seasons generally corresponded to infestation by forest tent caterpillar and the bruce spanworm (Operophera bruceata) (ESP, 1989). Although the survey was primarily designed to assess sugar maple decline, the study showed elevated declines for yellow and white birch, red maple (Acer rubrum) and black cherry (Prunus serotina). There were no discernible patterns in decline with respect to wet sulphate deposition.

In 1989, a three-year contract was awarded to Beak Consultants Limited (BEAK) to continue the Hardwood Decline Survey. The results from the 1989 and 1990 surveys are provided in this report.

2.0 STUDY OBJECTIVES

The primary objectives of the 1989 and 1990 surveys were to:

- re-evaluate the 100 trees in each of the survey plots;
- carry out maintenance work in each plot; and
- compare 1989 and 1990 data with the 1986 and 1987 data.

In addition to the above-mentioned objectives, BEAK extended the scope of work to include:

- correction and revision of plot location data;
- development of a quality assurance and quality control (QA/QC) field check program;
- development of a tree evaluation training program for crew members;
- development of a field manual for crew use; and
- the use of a Geographic Information System to summarize results from the survey, and to assess relationships between hardwood decline and environmental factors such as sulphate and nitrate deposition.

3.0 METHODOLOGY

3.1 Field Crew Selection

Four field crews were selected by BEAK for the 1989 survey and 3 crews were used for the 1990 work. Each crew consisted of two individuals. All crew members were university students with experience in forestry and fieldwork. The crew leaders had proven experience in leadership and tree identification.

3.2 Field Tasks

Each of the crews was responsible for assessing at least one-quarter (in 1989) or one-third (in 1990) of the survey plots. The crews began in the northern part of the Province in mid-July and progressed southward so that seasonal differences in canopy condition could be minimized.

At each of the plots, field crews performed the following activities:

- revised plot and location data;
- re-marked the plot and buffer zones;
- re-tagged sample trees; and
- re-assessed sample trees.

To facilitate finding plots in successive surveys, the T-bars used to identify the location of the plots were repainted. If the T-bars were removed or damaged, an appropriate permanent object such as a tree or fence-post was painted and recorded in the plot directions as a landmark.

Numbered aluminum tags were originally placed on survey trees at breast and/or stump height using galvanized steel nails. These tags and nails were removed and new tags were

installed at breast height using screws. At least 4 cm clearance was left between the screw head and the surface of the bark to allow for radial growth increases. The screws can be retracted during subsequent plot visits.

All sample trees were re-assessed for decline using the MOE technique outlined in Section 1.2.3. Independent observations by each member of the crew were combined, through a consultative process, into a single set of observations for each sample tree. Observations of tree injury and dead or fallen trees were also recorded.

3.3 Quality Assurance/Quality Control (QA/QC)

The Hardwood Decline Survey involves the visual assessment of a large number of trees by a relatively small number of individuals. To ensure data quality, BEAK initiated a quality assurance/quality control (QA/QC) program, which involved:

- thorough and detailed training in the field tasks required;
- development of a comprehensive field manual for each crew member;
- strict data handling and record keeping protocols;
- plot overlaps by a number of crews to evaluate assessment quality; and
- regular plot visits by experienced BEAK personnel.

Additional QC testing was conducted by the MOE in that all crew members were tested in the tree assessment technique prior to initiation of the study. Random plot visits were also made by MOE staff.

3.3.1 Crew Training

Field crews were trained by experienced BEAK personnel in early July of each year in:

- tree assessments;
- plot maintenance; and
- record-keeping and data handling.

A training program was conducted on several plots over a three-day period. Four plots were selected to cover a variety of decline types: two in the Muskoka region and two in the Peterborough region.

Field crew members were trained in tree assessments using the MOE technique that was used for the 1986 and 1987 assessments (McLaughlin et al., 1988). The specific skills developed during this three-day training program included:

- the ability to recognize common hardwood tree species;
- the recognition and ability to score the three important symptoms, namely:
  - dead branches,
  - undersized leaves, and
  - foliar chlorosis;
- the recognition and ability to score the impacts of insect defoliators on individual sample trees; and
- the recognition of various main stem injuries caused by forest tree diseases, management activities or other events.

Of particular importance to the success of the training program, and the validity of subsequent survey data, was that each crew member be able to assess the trees in a reproducible manner. To this end, individuals and crews were required to repeatedly assess a series of trees independently until all crew members were rating trees accurately and consistently.

Field crews were tested by experienced MOE personnel at the Halton Hills Conservation Area prior to commencement of each survey. Crews were asked to repeatedly rate a series of sugar maple trees having a range of decline symptoms. The crews were assessed with respect to the accuracy and reproducibility of decline component scores for each tree.

3.3.2 Data Handling and Communication

Crews were provided with carbonless duplicate decline assessment forms (see Figure 3). They were required to mail a copy of this form to BEAK (in previously labelled and stamped envelopes) within 24 hours of the plot visit, with the following:

- field notes;
- revised plot directions and location maps; and
- revised topographic maps.

The field notes recorded during each plot visit were to include:

- the time of crew arrival at the plot;
- a thorough list of maintenance activities performed at the plot;
- the overall site conditions, including any obvious signs of damage or change;
- the weather conditions;
- any recent changes in land use or development in the immediate vicinity of the plot;
- comments on specific problems in finding individual trees or plots;
- notes on general difficulties encountered during assessments or plot maintenance; and
- the time of crew departure from the plot.

The field notes and DI forms mailed to BEAK were put into one of 110 individual files. This ensured ready access to plot information, and that no data were lost (since two copies of the decline assessment forms existed).

After completing activities at each plot, the crews were required to call the BEAK Project Coordinator to:

- report progress to-date; and
- give a forecast of activities and travel path.

This regular communication allowed BEAK personnel to schedule unannounced spot checks and to monitor the overall progress of plot assessments.

3.3.3 The Field Manual

As a supplement to field training, a Hardwood Decline Survey Field Manual was prepared by BEAK and given to each crew member for reference. The manual included;

- the names and contact numbers for liaison officers from BEAK and the MOE;
- a detailed description of field tasks;
- contingency plans;
- a brief "To Do" and equipment lists;
- the MOE Tree Assessment Methodology Manual;
- a tree identification package; and
- a Hardwood Disease and Insect Identification package.

The manual was a useful addition to the QA/QC program because it saved valuable time in the field when crews were unsure of a task or when a problem arose.

3.3.4 Overlap Plots

To check the quality of tree assessments by each crew, a number of plots had assessments carried out by more than one crew. Scheduled overlaps occurred randomly throughout the study area. The data from the QA/QC programs were analyzed statistically (using analysis of variance and planned comparisons), and the results considered in view of the quality of crew assessments and the possibility of expanding this program in future years.

3.4 Data Analysis

Data collected during each survey were processed, edited and analyzed as described in Figure 4.

3.4.1 Tree Assessment Data

Upon the arrival of one copy of data at BEAK offices, information on the decline assessment forms was entered onto a Lotus-123 file. After editing and verification, all plot files were merged for statistical analysis. General statistics were then carried out by plot and species, including:

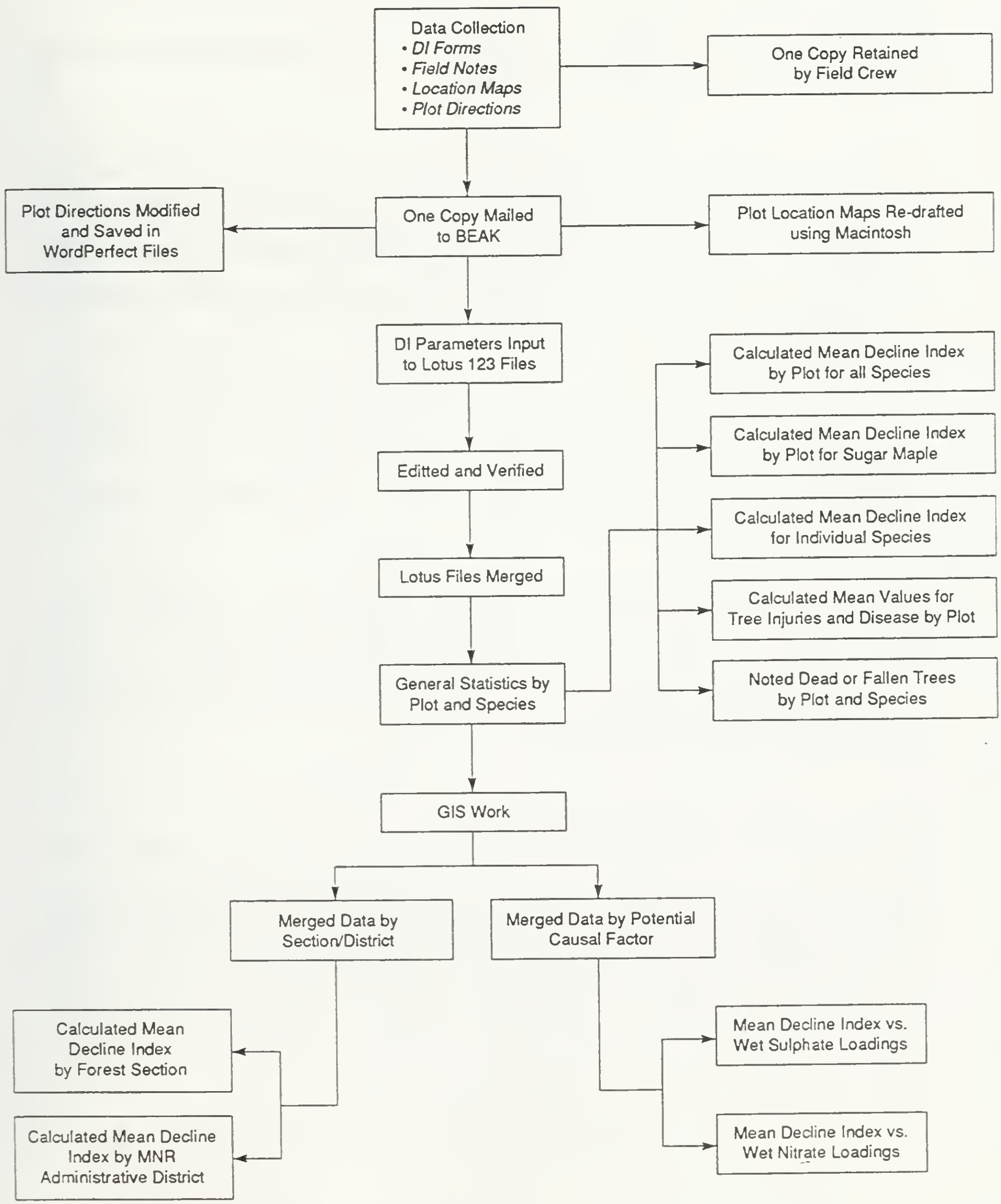
- mean DI by plot for all species combined;
- mean DI by plot for sugar maple;
- mean DI for individual species (across all plots);
- mean values for tree injuries and disease by plot; and
- noted dead or fallen trees by plot and by species.

In addition to these general statistics, the spatial characteristics of mean DI by plot were examined using Geographic Information System (GIS) analysis. SPANS (Spatial Analysis System), a PC raster-based GIS developed by TYDAC Technologies, was used to examine mean DI by plot in relation to:

- Forest Sections (Rowe, 1972);
- MNR Administrative Districts;
- wet sulphate deposition zones; and
- wet nitrate deposition zones.

These four spatial variables were digitized from previously published maps. Mean DI values by plot for 1989 and 1990 were derived from analysis of the data collected from each

Figure 4: Data Handling and Analysis



of the survey plots. Mean DI by plot for the 1986 and 1987 surveys (McIlveen et al., 1989 and ESP, 1989) were also input into SPANS. All files were converted from the SPANS system format to an ARC/INFO GIS system (ESRI). The files were then output to a HP Laserjet printer with an HPGL Plotter Cartridge.

For the analysis, each of the plots was assumed to be representative of forest conditions between plots. Interpolation between plots was carried out using the Thiessen Polygon (also known as Voronoi polygons or Dirichlet cells) Interpolation Modelling Technique. Maps showing the spatial distribution of mean DI by plot (for 1986, 1987, 1989 and 1990) were developed from this modelling approach.

Changes in mean DI by plot from one year to the next were also computed using GIS. These changes were noted by relative increases or decreases in one (or more) DI classes. Comparisons were made, by plot, for 1989-1990, 1987-1990, 1986-1990, 1987-1989, 1986-1989 and 1986-1987.

Following development of the mean decline index model (map), the relationship to other spatial variables, including forest Sections, MNR administrative Districts, wet sulphate deposition zones and wet nitrate deposition zones, was examined using an overlay approach. Maps and cross-tabulation tables were output.

3.4.2 Plot Directions and Location Maps

Revised plot access information and location sketches are compiled in a separate document. Sketches were accomplished with the aid of a Apple Macintosh microcomputer. Future changes can be made readily to accommodate changes in road alignments, landmarks, etc., or to correct errors.

4.0 RESULTS AND DISCUSSION

4.1 Hardwood Decline Assessment Results

4.1.1 Decline by Survey Plot

The mean decline index (DI) for each plot in 1986, 1987, 1989 and 1990 is summarized in Table 4. Considerable variation in mean DI is evident between plots within the same year and also at any given plot between years. The mean DI for hardwood trees in Ontario was 13 in 1990, 11 in 1989, 15 in 1987 and 14 in 1986. For interpretation and mapping purposes, five decline classes (and relative decline ratings) were established by the MOE as follows:

Decline Category	Range of DI	Relative Decline Rating
1	< 11	Very low
2	11-15.99	Low
3	16-20.99	Moderate
4	21-24.99	High
5	25+	Severe

Overall, hardwood forest decline in Ontario for 1986, 1987, 1989 and 1990 was rated as low. The spatial distribution of mean DI across the Province is illustrated for 1990, 1989, 1987 and 1986 in Figures 5 to 8, respectively. The mean DI for each plot was assigned to one of the five decline categories and mapped using the GIS. Individual Thiessen polygons were drawn around each plot. The size of the polygon depends on the proximity of one plot to another. Plots separated by greater distances are represented by larger polygons. Data collected at each plot are assumed to be representative of the area encompassed by each polygon. The approximate area represented by each plot is listed in Table 5. Some plots,

TABLE 4: MEAN DECLINE INDEX[1] (DI) BY PLOT (for all species)

Plot No.[2]	1986	1987	1989	1990	Mean 1986-1990	Plot No.[2]	1986	1987	1989	1990	Mean 1986-1990	Plot No.[2]	1986	1987	1989	1990	Mean 1986-1990
1	15	10	11	7	11	41	22	24	19	17	21	81	13	5	10	19	12
2	15	29	16	13	18	42	7	8	2	3	5	82	13	5	9	19	12
3	14	17	18	18	17	43	16	16	10	8	13	83	12	5	7	11	9
4	17	25	16	16	19	44	14	11	6	4	9	84	8	15	7	13	11
5	10	23	15	7	14	45	19	14	13	14	15	85	7	10	2	7	7
6	11	10	8	11	10	46	13	14	5	6	10	86	15	4	6	9	9
7	9	9	6	12	9	47	15	20	8	12	14	87	13	14	8	9	11
8	13	24	6	12	14	48	15	14	7	6	11	88	15	21	1	14	13
9	15	7	4	9	9	49	15	13	4	7	10	89	18	19	18	15	18
10	13	3	6	11	8	50	19	23	15	8	16	90	19	20	19	12	18
11	18	11	7	8	11	51	12	13	4	8	9	91	21	21	26	19	22
12	9	2	5	6	6	52	14	15	11	13	13	92	12	15	21	13	15
13	20	17	12	16	16	53	11	14	2	6	8	93	15	19	12	12	15
14	11	16	5	9	10	54	9	4	4	7	6	94	15	18	7	13	13
15	14	12	7	9	11	55	18	15	9	9	13	95	18	26	20	-[3]	21
16	16	21	13	20	18	56	16	23	13	15	17	96	17	28	10	14	17
17	25	25	27	24	25	57	6	9	8	11	9	97	18	27	12	11	17
18	10	20	26	14	18	58	15	21	12	10	15	98	19	25	14	14	18
19	12	16	11	7	12	59	8	2	10	16	9	99	15	27	18	15	19
20	16	19	8	13	14	60	6	11	6	13	9	100	14	33	12	16	19
21	11	12	9	6	10	61	20	21	17	21	20	101	14	16	21	12	16
22	9	10	2	6	7	62	9	11	7	13	10	102	11	11	6	11	10
23	12	11	8	9	10	63	17	9	18	13	14	103	16	18	9	15	15
24	16	14	8	10	12	64	21	12	18	22	18	104	13	27	15	11	17
25	10	10	7	12	10	65	16	21	28	34	25	105	12	14	4	14	11
26	15	26	9	12	16	66	19	22	25	35	25	106	16	16	21	18	18
27	14	15	13	18	15	67	16	11	15	13	14	107	12	18	25	21	19
28	18	22	32	19	23	68	18	15	1	10	11	108	14	12	8	11	11
29	21	29	27	18	24	69	16	12	3	4	9	109	19	16	8	6	12
30	17	30	33	25	26	70	14	14	10	15	13	110	13	11	4	7	9
31	13	21	25	18	19	71	14	5	10	17	12	TOTAL					
32	12	14	17	14	14	72	5	6	17	11	10	PLOT	14	15	11	13	13
33	13	14	16	13	14	73	10	2	15	15	11	MEAN					
34	12	18	22	20	18	74	4	12	8	12	9						
35	15	19	18	14	17	75	8	5	7	11	8						
36	11	11	13	9	11	76	12	17	16	18	16						
37	29	25	22	24	25	77	15	17	1	14	15						
38	20	22	17	22	20	78	7	14	10	13	11						
39	15	17	11	15	15	79	12	0	9	13	9						
40	11	12	8	8	10	80	14	18	9	16	14						

[1] Mean DIs calculated as outlined in Section 3.0.

[2] Plot locations as illustrated in Figure 1.

[3] Plot not surveyed in 1990.

Figure 5: Mean Decline Index (DI) 1990

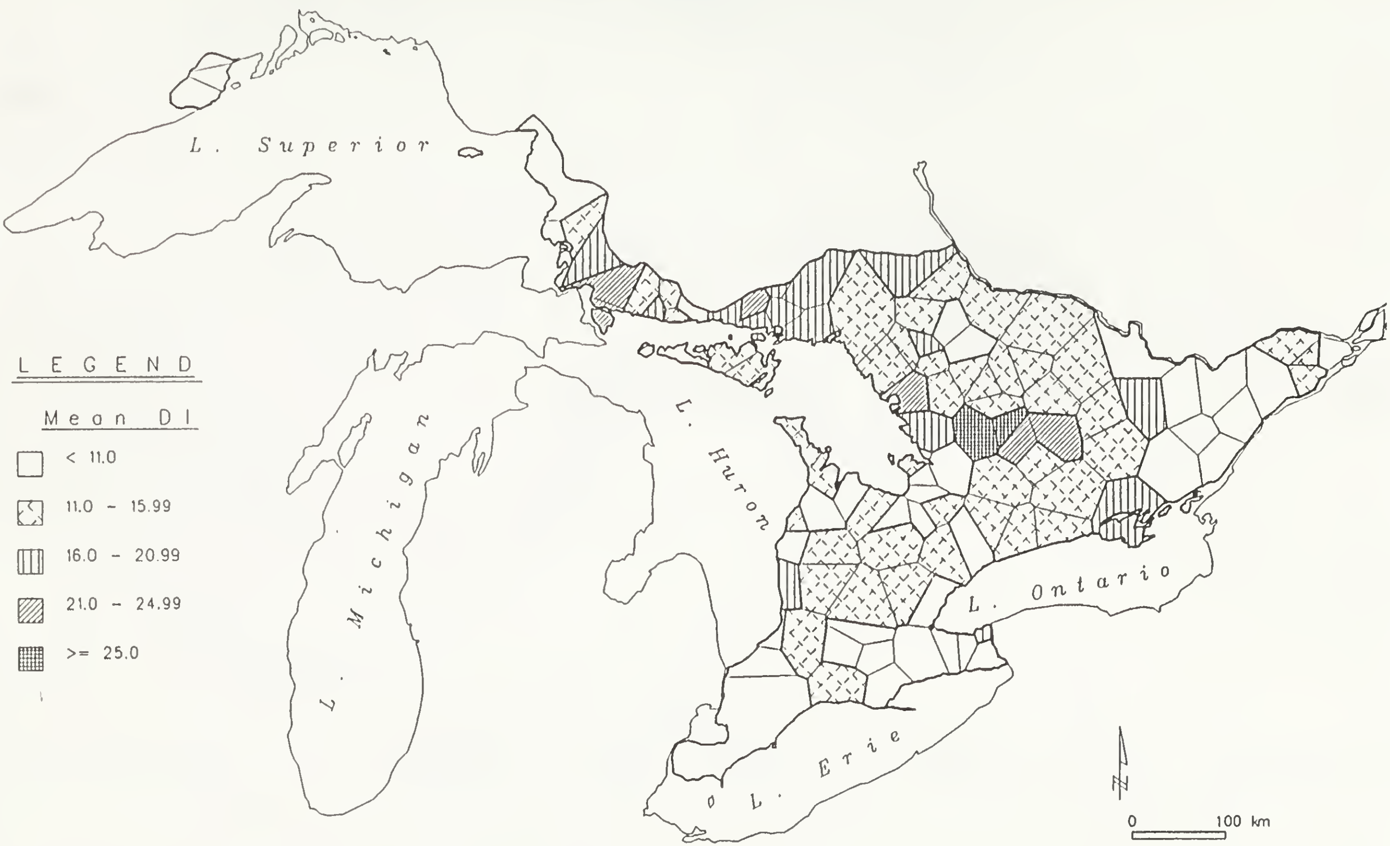
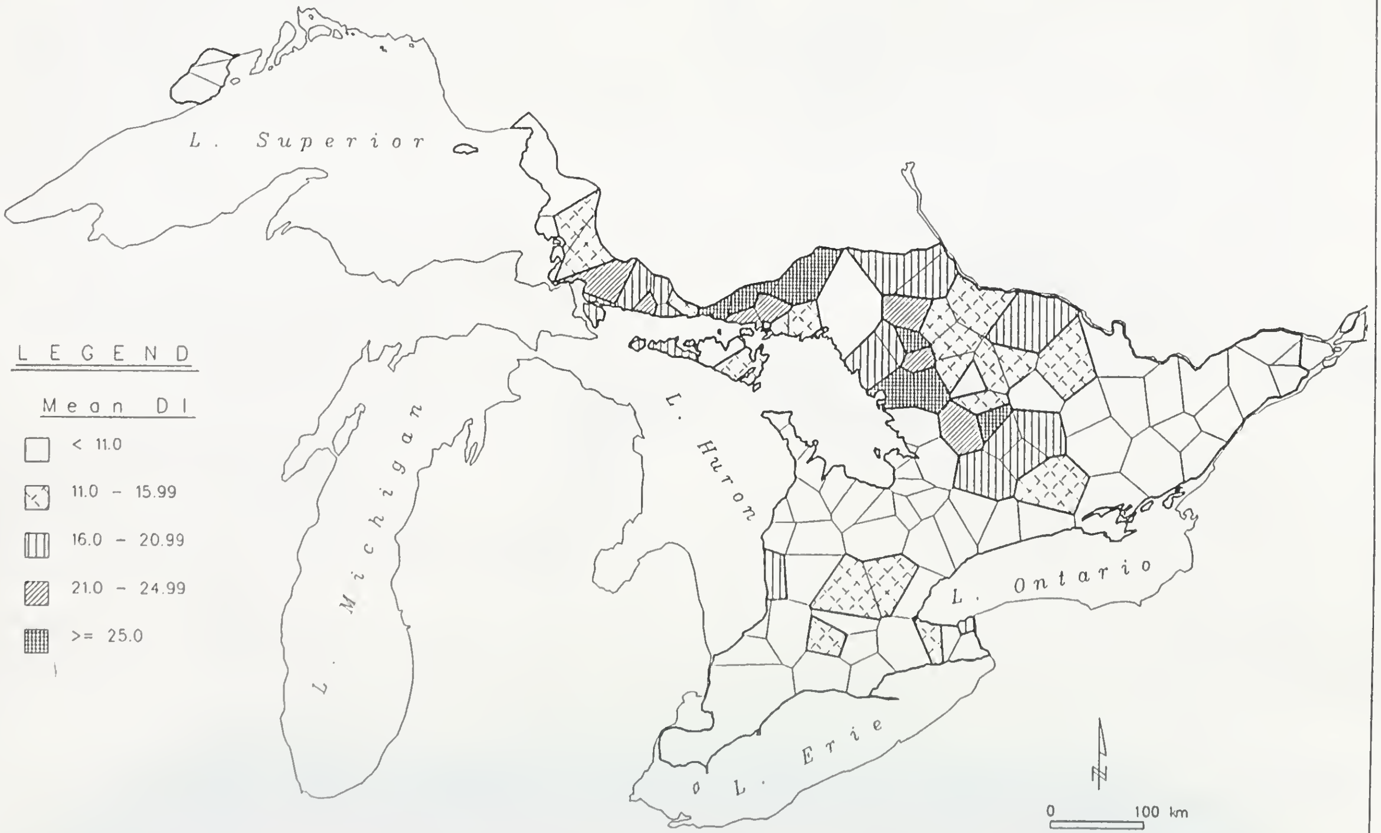


Figure 6: Mean Decline Index (DI) 1989



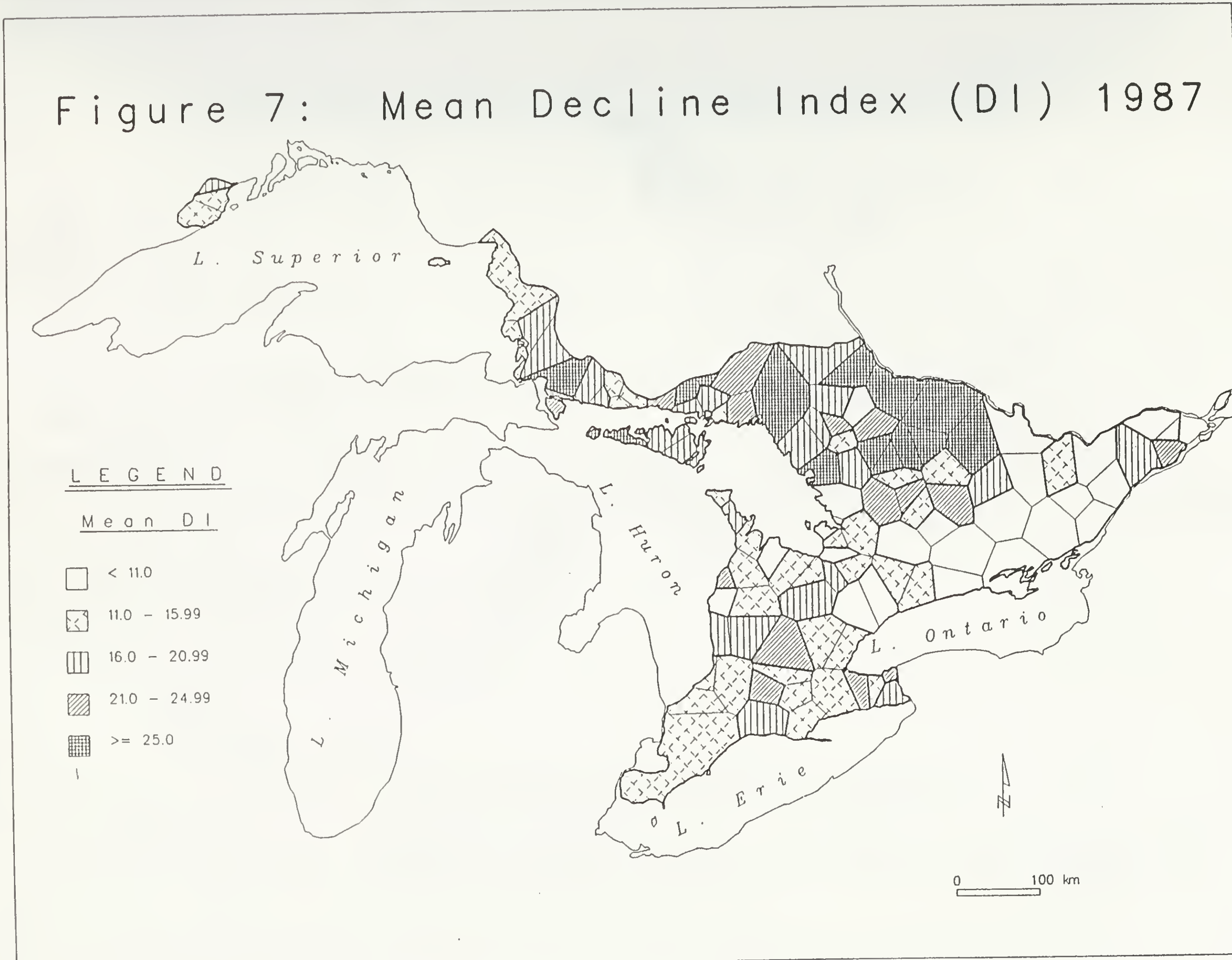


Figure 7: Mean Decline Index (DI) 1987
L. Superior
L. Michigan
L. Huron
L. Ontario
L. Erie
LEGEND
Mean DI
< 11.0
11.0 – 15.99
16.0 – 20.99
21.0 – 24.99
>= 25.0
0
100 km

Figure 8: Mean Decline Index (DI) 1986

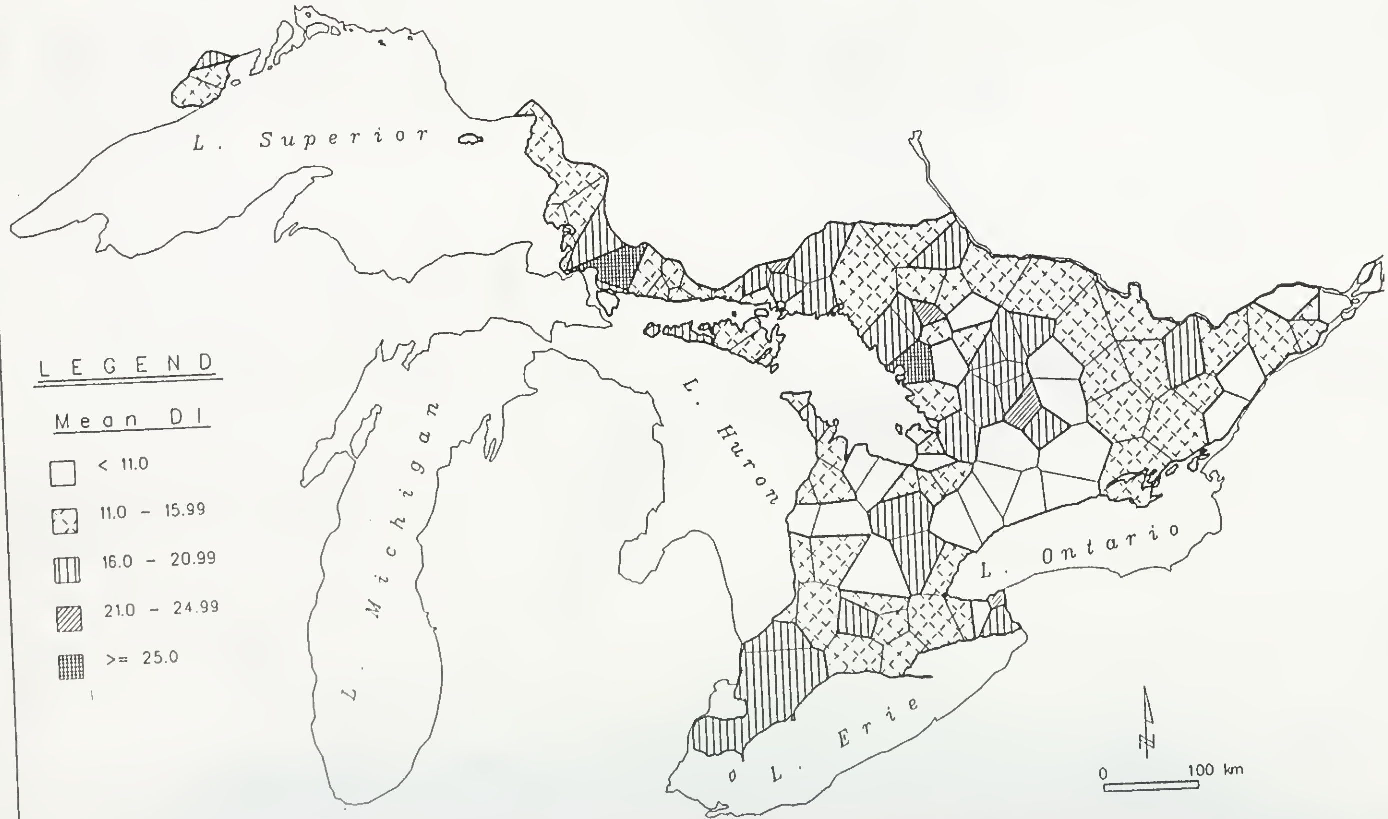


TABLE 5: THE SPATIAL COVERAGE OF EACH SURVEY PLOT[1]

Plot	Total Area Represented (km²)	% of Total Hardwood Forest Area	Plot	Total Area Represented (km²)	% of Total Hardwood Forest Area	Plot	Total Area Represented (km²)	% of Total Hardwood Forest Area
1	1,149	0.7	41	249	0.1	81	2,446	1.4
2	954	0.6	42	869	0.5	82	3,500	2.0
3	2,735	1.6	43	836	0.5	83	3,576	2.1
4	1,860	1.1	44	1,420	0.8	84	1,536	0.9
5	1,372	0.8	45	2,285	1.3	85	1,023	0.6
6	425	0.2	46	1,515	0.9	86	1,234	0.7
7	1,525	0.9	47	2,207	1.3	87	1,487	0.9
8	891	0.5	48	1,069	0.6	88	407	0.2
9	2,782	1.6	49	1,065	0.6	89	1,921	1.1
10	2,424	1.4	50	1,232	0.7	90	806	0.5
11	2,247	1.3	51	414	0.2	91	613	0.4
12	1,795	1.0	52	941	0.6	92	706	0.4
13	1,879	1.1	53	2,454	1.4	93	1,221	0.7
14	2,649	1.5	54	1,511	0.9	94	1,044	0.6
15	3,521	2.1	55	541	0.3	95[2]	779	0.5
16	1,186	0.7	56	2,960	1.7	96	810	0.5
17	1,435	0.8	57	1,739	1.0	97	1,282	0.8
18	1,407	0.8	58	879	0.5	98	1,308	0.8
19	658	0.4	59	1,693	1.0	99	4,030	2.3
20	2,493	1.4	60	1,734	1.0	100	3,346	2.0
21	782	0.5	61	2,016	1.2	101	1,578	0.9
22	627	0.4	62	1,774	1.0	102	375	0.2
23	448	0.3	63	1,209	0.7	103	557	0.3
24	1,825	1.1	64	1,047	0.6	104	2,781	1.6
25	453	0.3	65	780	0.5	105	1,004	0.6
26	5,119	3.0	66	1,954	1.1	106	833	0.5
27	431	0.3	67	971	0.6	107	604	0.4
28	2,627	1.5	68	1,509	0.9	108	765	0.4
29	260	0.2	69	8,205	4.8	109	891	0.5
30	673	0.4	70	2,601	1.5	110	1,513	0.9
31	515	0.3	71	1,772	1.0	Total	172,000	100.0
32	314	0.2	72	2,558	1.5			
33	578	0.3	73	3,314	1.9			
34	406	0.2	74	1,602	0.9			
35	1,152	0.7	75	2,093	1.2			
36	481	0.3	76	1,049	0.6			
37	1,857	1.1	77	2,239	1.3			
38	594	0.3	78	1,899	1.1			
39	1,465	0.8	79	3,042	1.8			
40	809	0.5	80	1,974	1.1			

[1] As estimated by Thiessen polygons.

[2] Area of Plot No. 95 used in 1986, 1987 and 1989 survey years only.

such as No. 69 in the Chatham MNR District, represent large areas of the Province, i.e., 4.8%, while other plots, such as No. 41 in the Niagara MNR District, represent much smaller areas (0.1%). The differences reflect the relative difficulties in locating suitable plots in different parts of the Province.

In 1990, severe hardwood decline (plot mean DI > 25) was found in 3 (3%) of the survey plots; in the Sudbury (Plot 30) and Minden (Plots 65,66) MNR Districts. Severe decline was reported in 6% of the Province in 1989, and was identified in the following MNR Districts and plots:

- Sudbury (Plots 28, 29);
- Espanola (Plot 30);
- Parry Sound (Plots 17, 18, 91); and
- Minden (Plot 65).

In 1987, severe hardwood decline was found to occur in 9% of the plots, in these MNR Districts:

- Bracebridge (Plot 2);
- Sudbury (Plots 26, 29);
- Espanola (Plots 30, 95);
- Algonquin Park (Plots 96, 97, 99);
- Pembroke (Plot 100); and
- North Bay (Plot 104).

Severe decline in 1986 was noted only for Plot 37 (DI = 29) in the Sault Ste. Marie District. The Sudbury and Minden Districts reported severe decline in 1989 and 1990, while only the Sudbury and Espanola Districts reported severe decline in both 1987 and 1989.

The pattern of decline in 1986, 1987, 1989 and 1990, for all species combined, is illustrated in Figure 9. Considerable differences are evident when the proportion of total plots within each relative decline class are compared. Thirty-two percent of all plots in 1990 were within the very low decline category, i.e., DI less than 11. This compares with 53% for 1989, 21% for 1987 and 17% for 1986. The relative size and location of these decline changes can be determined by comparing the mean DI for each plot over the four-year period. For presentation purposes, changes are expressed relative to the number of DI classes that any given plot has moved from one year to another. Plots that have increased by a given number of class changes have deteriorated in condition. Those that have decreased by a number of class changes have improved in health.

Individual plot changes for 1989 to 1990, 1987 to 1990, 1986 to 1990, 1987 to 1989, 1986 to 1989 and 1986 to 1987 are listed in Table 6 and shown graphically in Figures 10 to 15. Plot changes of more than one decline class are considered significant (pers. comm., D. McLaughlin, 1992). Between 1989 and 1990, 91% of all plots either had no mean change or increased/decreased by one decline class. This compares with 78% between 1987 and 1990, 90% between 1986 and 1990, 72% between 1987 and 1989, 82% between 1986 and 1989 and 83% between 1986 and 1987. Therefore, the greatest change in tree condition occurred between 1987 and 1989, with 28% of the plots reporting a change in DI of more than one decline class. Of this 28%, 4% represented increases in decline class (deterioration in tree health) and 25% represented decreases in decline class (improvement in tree health). The smallest change in tree condition occurred between 1989 and 1990 (9%).

Most of the change in decline occurring between 1987 and 1989 was reported in the Sudbury and Algonquin Park MNR Districts. Mean plot DI decreased by four decline classes at single plots within each of these two Districts. Mean plot DI decreases of three decline classes were also recorded at two plots within the Algonquin Park MNR District, and at individual plots in the Bracebridge, Cornwall, Owen Sound, Pembroke and North Bay MNR Districts.

FIGURE 9: THE PROPORTION OF PLOTS IN EACH DECLINE CLASS

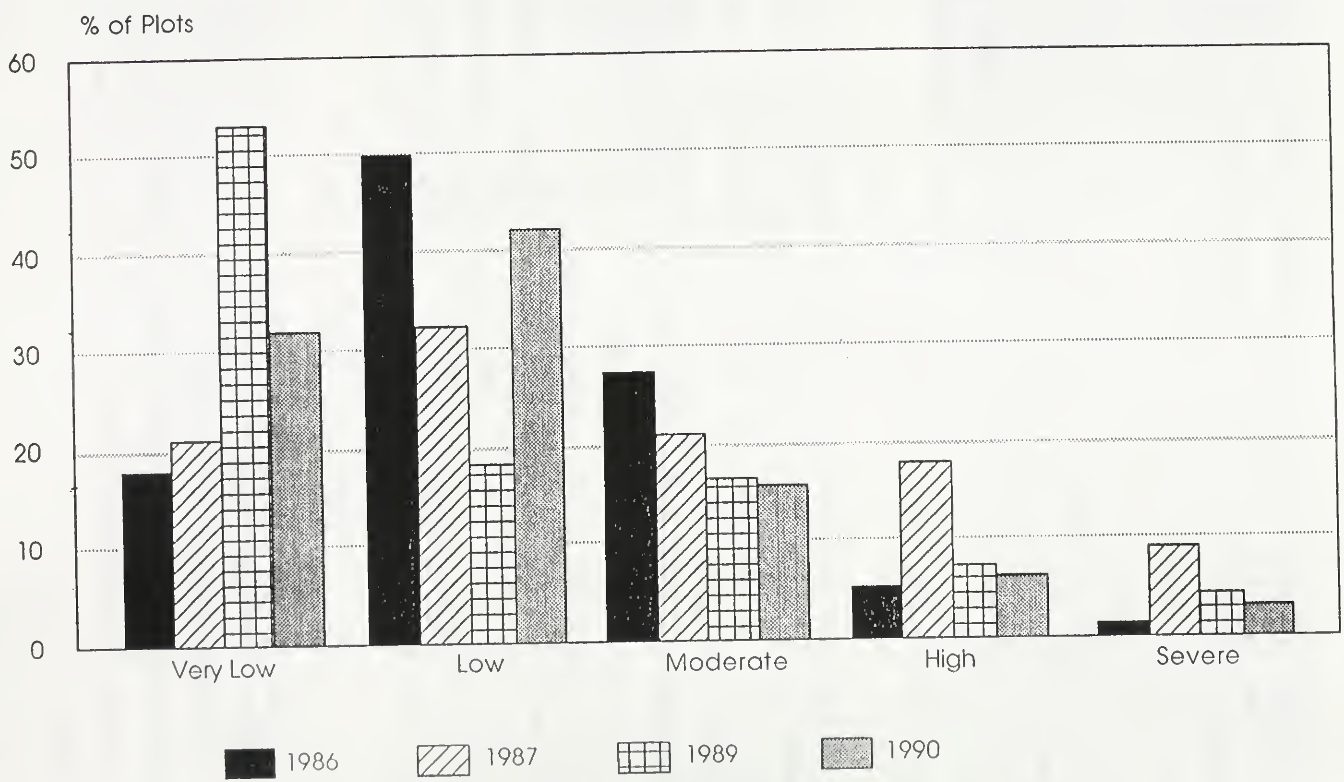


TABLE 6: MEAN DECLINE INDEX (DI) CHANGES BY SURVEY PLOT

Decline Class Change[1]	No. of Plots	Plot Numbers
1989 to 1990		
Increase by 2 classes	3	71, 81, 82
Increase by 1 class	32	6, 7, 8, 13, 16, 20, 25, 26, 27, 38, 47, 52, 59, 60, 61, 62, 64, 66, 70, 74, 75, 77, 78, 79, 80, 84, 88, 94, 96, 102, 103, 105
No change	48	2, 3, 9, 10, 11, 12, 14, 15, 19, 21, 22, 23, 24, 37, 39, 40, 41, 42, 43, 44, 45, 46, 48, 49, 51, 53, 54, 55, 56, 57, 65, 67, 68, 69, 73, 76, 83, 85, 86, 87, 93, 97, 98, 100, 104, 108, 109, 110
Decrease by 1 class	19	1, 4, 5, 17, 30, 32, 33, 34, 35, 36, 50, 58, 63, 72, 89, 90, 99, 106, 107
Decrease by 2 classes	6	28, 29, 31, 91, 92, 101
Decrease by 3 classes	1	18
Not assessed	1	95
1987 to 1990		
Increase by 2 classes	4	64, 71, 81, 82
Increase by 1 class	12	6, 7, 25, 27, 59, 63, 65, 66, 72, 73, 75, 79
No change	33	1, 3, 9, 10, 12, 13, 22, 32, 33, 34, 38, 42, 45, 52, 54, 57, 60, 61, 62, 67, 70, 74, 76, 78, 83, 84, 85, 86, 92, 102, 105, 106, 107
Decrease by 1 class	40	11, 15, 16, 17, 18, 20, 21, 23, 24, 28, 30, 31, 35, 36, 37, 39, 40, 41, 44, 46, 47, 48, 49, 51, 53, 55, 68, 69, 77, 80, 87, 89, 90, 91, 93, 94, 101, 103, 108, 110
Decrease by 2 classes	8	8, 14, 19, 29, 43, 56, 88, 109
Decrease by 3 classes	12	2, 4, 5, 26, 50, 58, 96, 97, 98, 99, 100, 104
Not assessed	1	95

TABLE 6: MEAN DECLINE INDEX (DI) CHANGES BY SURVEY PLOT (Cont'd)

Decline Class Change[1]	No. of Plots	Plot Numbers
1986 to 1990		
Increase by 2 classes	3	18, 65, 66
Increase by 1 class	23	3, 7, 25, 27, 30, 31, 34, 38, 59, 60, 61, 62, 71, 72, 73, 74, 75, 76, 78, 81, 82, 84, 107
No change	36	2, 5, 6, 8, 12, 13, 16, 22, 26, 28, 32, 33, 35, 39, 42, 47, 52, 54, 57, 64, 70, 77, 79, 80, 85, 88, 92, 93, 94, 99, 100, 101, 102, 104, 105, 106
Decrease by 1 class	39	1, 4, 9, 10, 14, 15, 17, 19, 20, 21, 23, 29, 36, 37, 40, 41, 44, 45, 46, 48, 49, 51, 53, 56, 58, 63, 67, 83, 86, 87, 89, 90, 91, 96, 97, 98, 103, 108, 110
Decrease by 2 classes	8	11, 24, 43, 50, 55, 68, 69, 109
Not assessed	1	95
1987 to 1989		
Increase by 2 classes	4	18, 63, 72, 92
Increase by 1 class	13	1, 28, 31, 32, 33, 34, 64, 65, 73, 91, 101, 106, 107
No change	32	3, 6, 7, 9, 10, 12, 17, 22, 25, 27, 29, 30, 35, 36, 42, 45, 54, 57, 59, 66, 67, 71, 75, 76, 79, 81, 82, 83, 85, 86, 89, 90
Decrease by 1 class	34	11, 13, 15, 21, 23, 24, 37, 38, 39, 40, 41, 44, 46, 48, 49, 51, 52, 53, 55, 60, 61, 62, 68, 69, 70, 74, 78, 84, 87, 93, 102, 105, 108, 110
Decrease by 2 classes	18	4, 5, 14, 16, 19, 20, 43, 47, 50, 56, 58, 77, 80, 94, 95, 99, 103, 109
Decrease by 3 classes	7	2, 8, 88, 97, 98, 100, 104
Decrease by 4 classes	2	26, 96

TABLE 6: MEAN DECLINE INDEX (DI) CHANGES BY SURVEY PLOT (Cont'd)

Decline Class Change[1]	No. of Plots	Plot Numbers
1986 to 1989		
Increase by 4 classes	1	18
Increase by 3 classes	1	31
Increase by 2 classes	8	28, 30, 34, 65, 72, 92, 101, 107
Increase by 1 class	12	3, 5, 29, 32, 33, 35, 66, 73, 76, 91, 99, 106
No change	32	1, 2, 4, 7, 12, 17, 22, 25, 27, 36, 38, 39, 42, 54, 57, 58, 59, 60, 61, 62, 63, 74, 75, 78, 84, 85, 89, 90, 93, 95, 100, 104
Decrease by 1 class	46	6, 8, 9, 10, 13, 14, 15, 16, 19, 21, 23, 26, 37, 40, 41, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 56, 64, 67, 70, 71, 77, 79, 80, 81, 82, 83, 86, 87, 88, 94, 97, 98, 102, 105, 108, 110
Decrease by 2 classes	10	11, 20, 24, 43, 55, 68,69, 96, 103, 109
1986 to 1987		
Increase by 3 classes	6	2, 5, 26, 99, 100, 104
Increase by 2 classes	11	4, 8, 18, 30, 31, 58, 88, 95, 96, 97, 98
Increase by 1 class	29	1, 3, 14, 16, 19, 28, 29, 34, 35, 38, 39, 47, 50, 56, 60, 61, 62, 65, 66, 74, 76, 77, 78, 80, 84, 93, 94, 101, 107
No change	46	7, 12, 13, 15, 17, 20, 21, 22, 23, 25, 27, 32, 33, 36, 37, 40, 41, 42, 43, 44, 46, 48, 49, 51, 52, 53, 54, 57, 59, 70, 72, 73, 75, 85, 87, 89, 90, 91, 92, 102, 103, 105, 106, 108, 109, 110
Decrease by 1 class	16	6, 9, 10, 11, 24, 45, 55, 67, 68, 69, 71, 79, 81, 82, 83, 86
Decrease by 2 classes	2	63, 64

[1] Increase in decline class - deterioration in tree health.
Decrease in decline class - improvement in tree health.

Figure 10: Decline Index (DI) Change 1989 to 1990

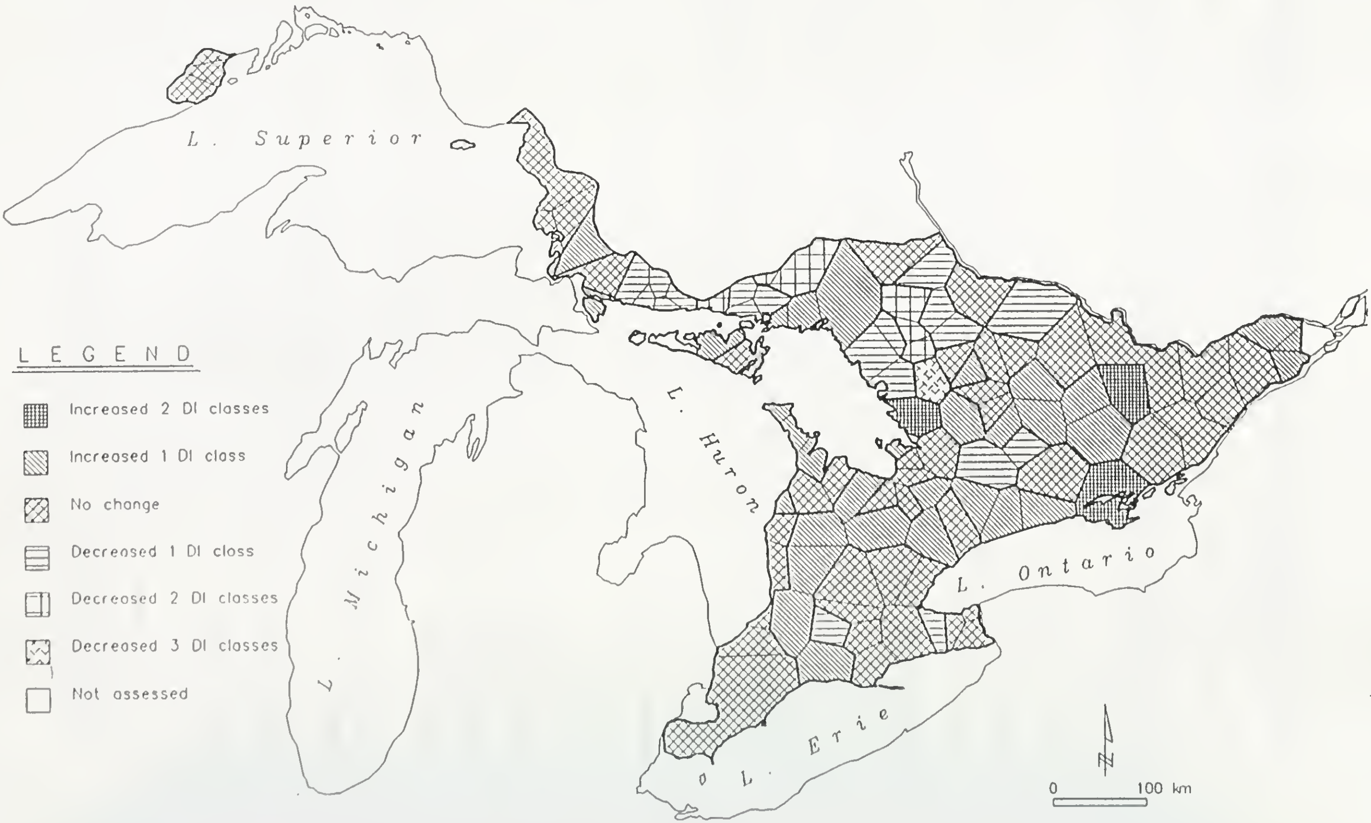


Figure 11: Decline Index (DI) Change 1987 to 1990

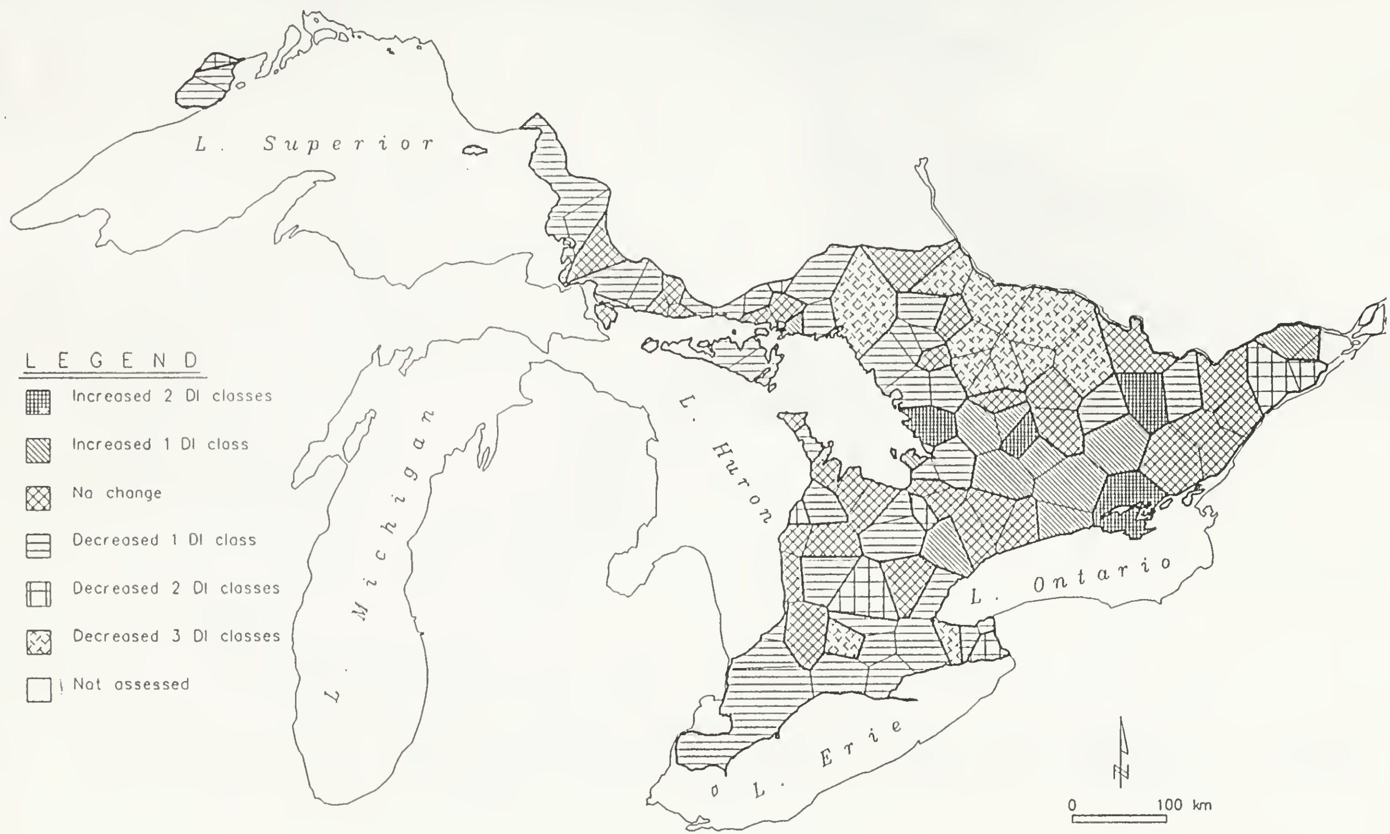


Figure 12: Decline Index (DI) Change 1986 to 1990

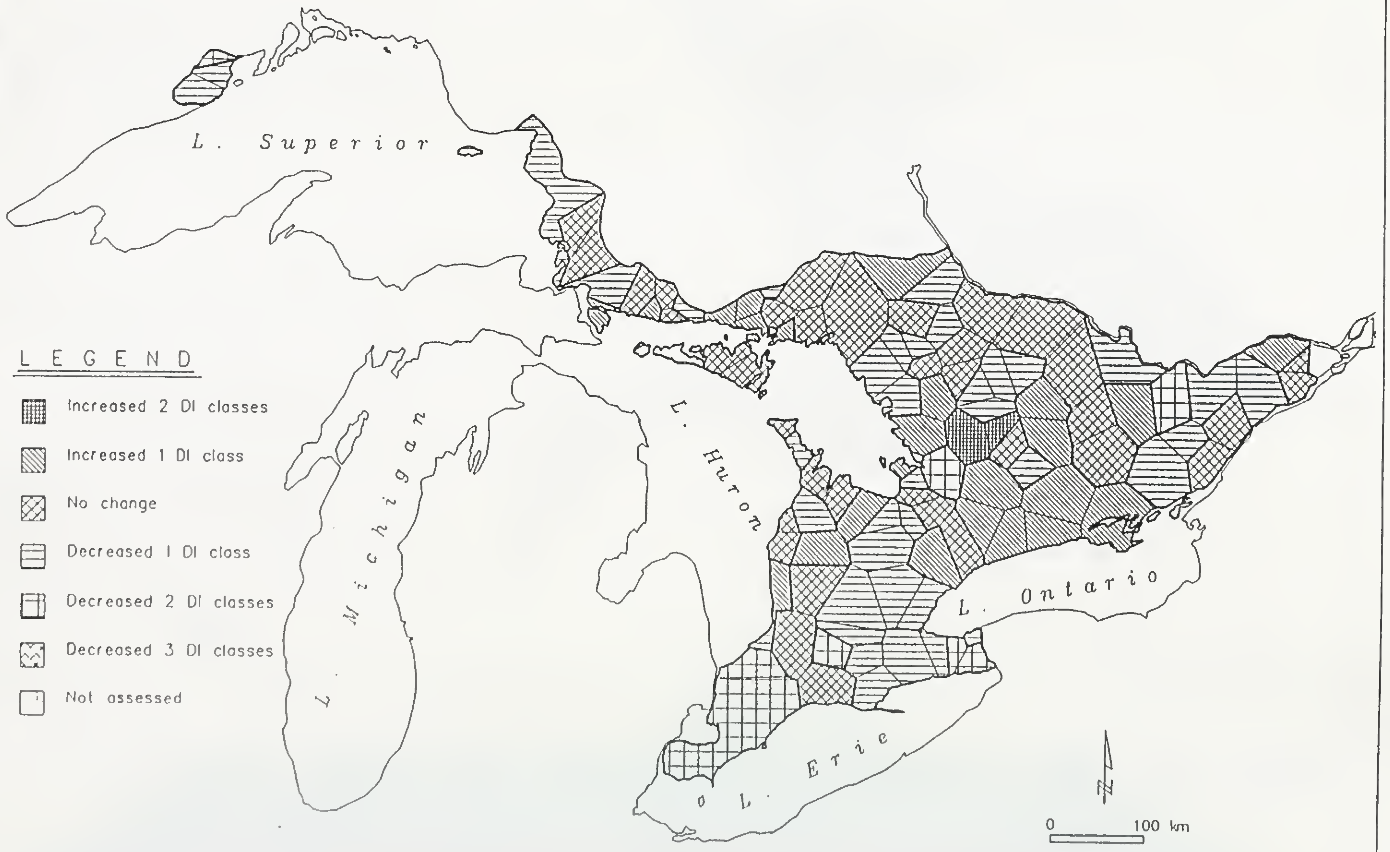


Figure 13: Decline Index (DI) Change 1987 to 1989

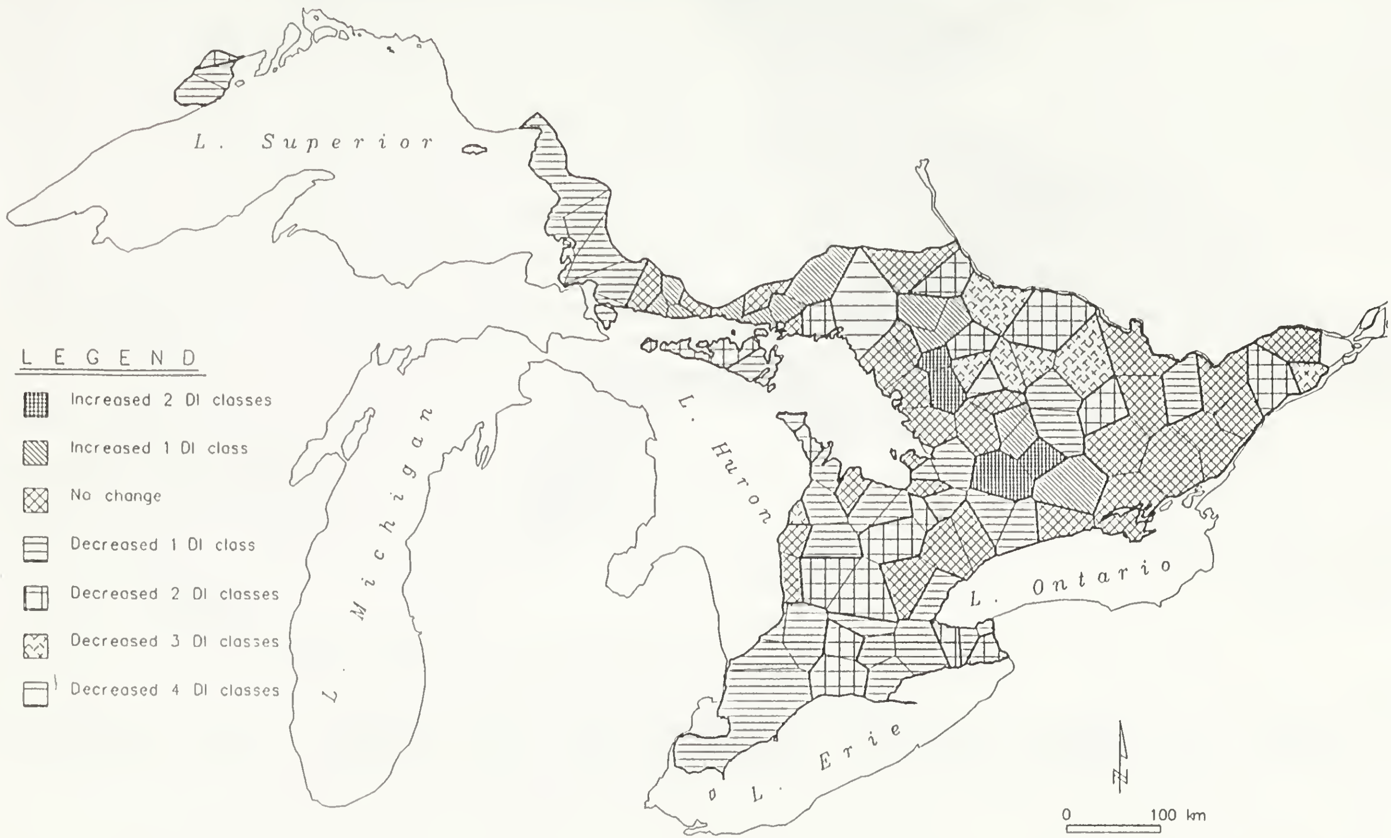


Figure 14: Decline Index (DI) Change 1986 to 1989

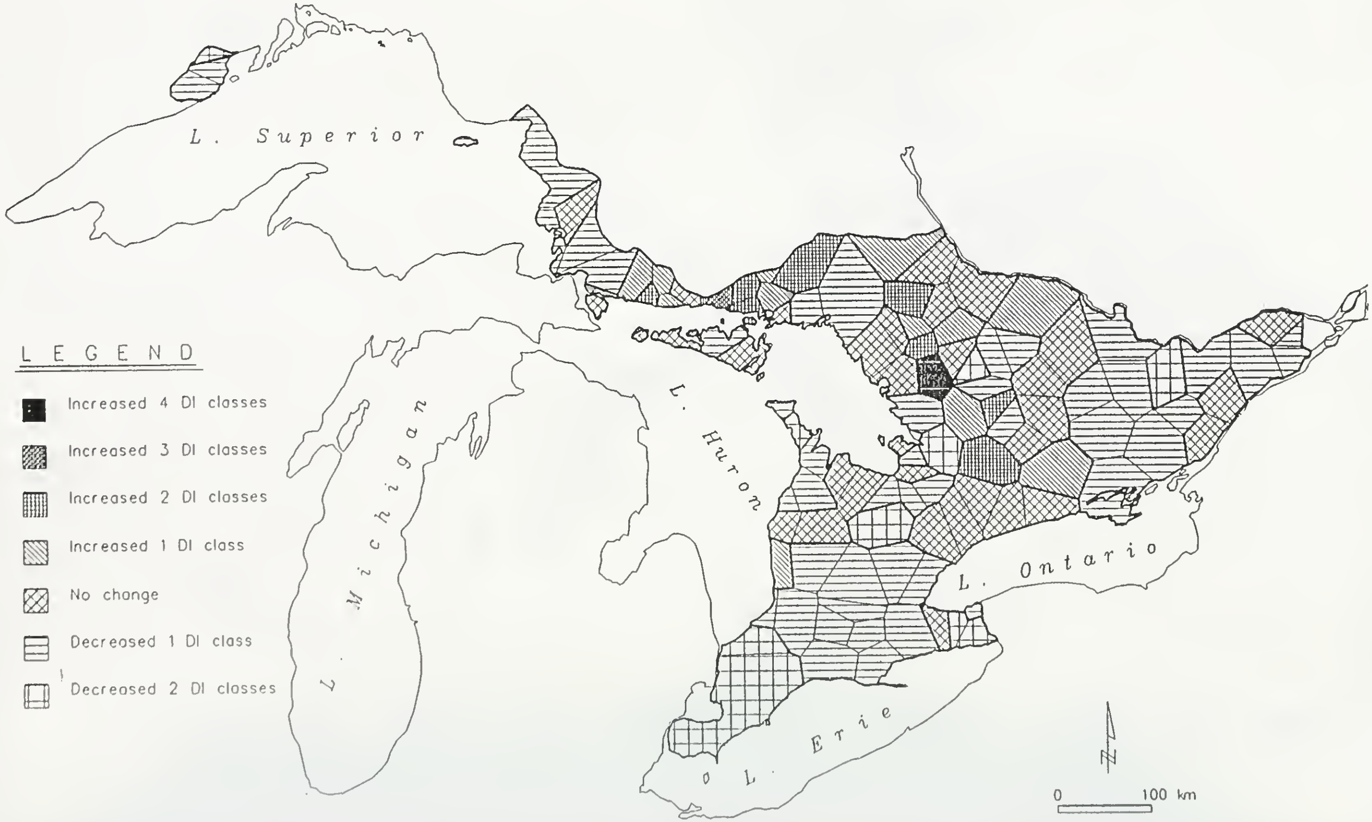
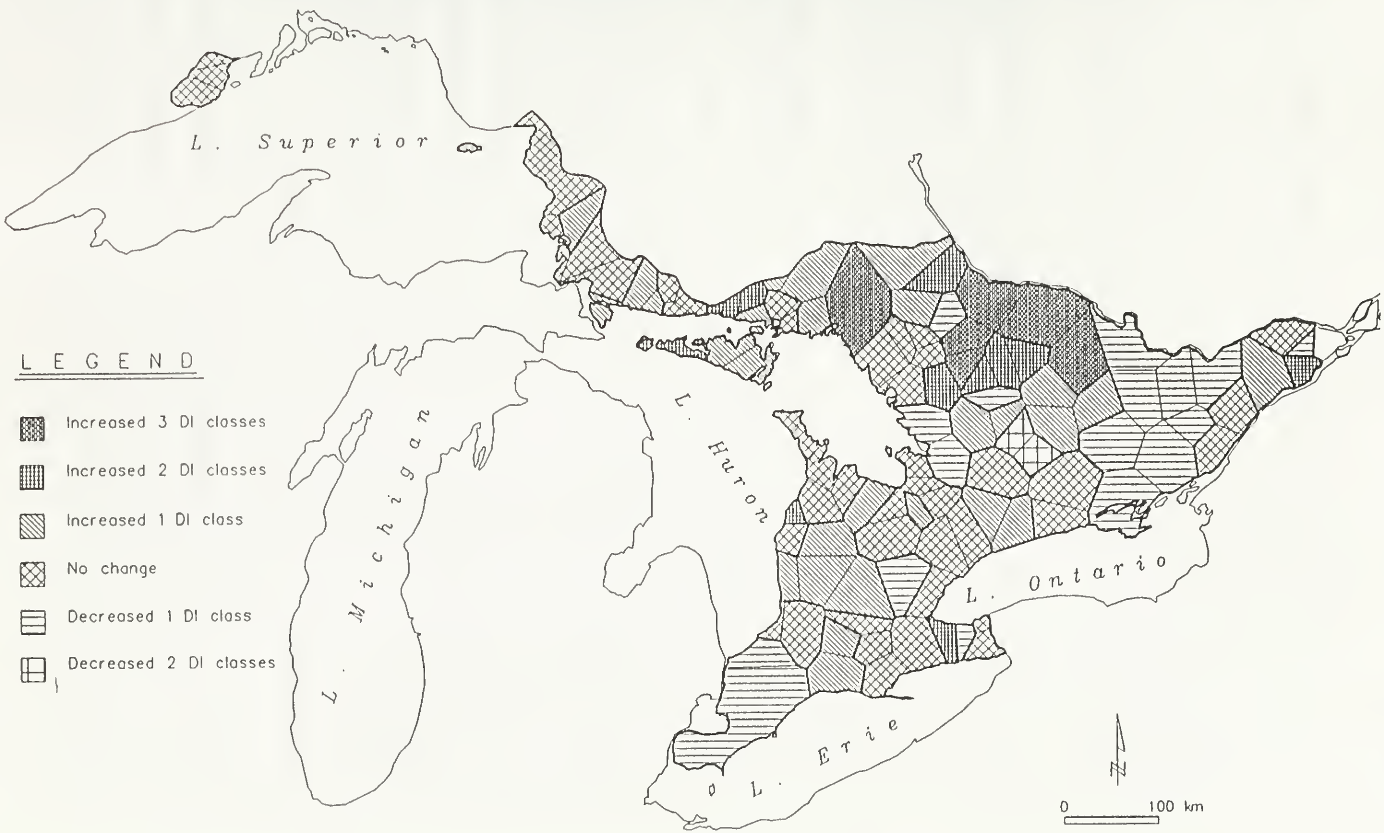


Figure 15: Decline Index (DI) Change 1986 to 1987



The most substantial change in individual mean plot DI between 1989 and 1990 occurred in the Parry Sound MNR District (Plot 18), where there was a decrease of three decline classes. Increases in mean plot DIs of two decline classes occurred at individual plots in the Parry Sound, Tweed and Napanee MNR Districts. Decreases in average plot DIs of two decline classes were recorded at two plots in both the Parry Sound and Sudbury MNR Districts and at single plots in each of the Espanola and North Bay MNR Districts.

Between 1986 and 1989, plots in the Bracebridge, Sudbury, Algonquin Park, Pembroke and North Bay MNR Districts varied considerably in condition. Between 1986 and 1987, substantial decline, as indicated by mean plot DI increases of three decline classes, was reported at the following 6 plots: Bracebridge (Plots 2, 5); Sudbury (Plot 26); Algonquin Park (Plot 99); Pembroke (Plot 100) and North Bay (Plot 104). From 1987 to 1989, the mean DI values at these same plots fell considerably. During this latter period, reductions in mean DIs led to a decrease of four decline classes at Plot 26; three classes at Plots 2, 100 and 104; and two classes at Plots 5 and 99.

On 22 and 23 June 1989, MOE representatives visited 34 of the 110 hardwood decline survey plots to evaluate the extent of defoliation by forest tent caterpillar. These plots were: 2, 5, 17, 18, 19, 20, 21, 22, 23, 24, 25, 52, 59, 60, 61, 62, 63, 64, 65, 66, 67, 71, 72, 73, 74, 84, 85, 91, 92, 96, 97, 102, 103 and 105. None of the plots in the Bracebridge, Parry Sound and Algonquin Park MNR Districts were significantly defoliated, although extensive defoliation of poplar and birch was seen in the vicinity of Sundridge and Magnetawan. Plots in Simcoe County and along the southern shore of Georgian Bay and through the Bruce Peninsula had marginal to no defoliation of sugar maple, although feeding by tent caterpillar was more common on poplar, ash and cherry.

Forest tent caterpillar was present at all plots in and around Peterborough County, but there was no significant defoliation on sugar maple. Gypsy moth (Lymantria dispar) was more common in the vicinity of the four most southerly plots (59, 60, 73 and 74), although defoliation was restricted to oak. Forest tent caterpillar defoliation of all deciduous species

was severe in the vicinity of Buckhorn and Gooderham, but the plots in these areas were not affected.

The increased decline from 1986 to 1987 may largely be explained by defoliation of sugar maple in 1987 (ESP, 1989). The improved tree health apparent from 1987 to 1989 may be explained by minimal-to-no defoliation in 1989 and the improvement in condition of trees which had been severely defoliated in 1987. This observation is also reflected in the individual species DI and mortality rates. Those plots showing increased decline from 1987 to 1989 do not necessarily indicate a "flaw" in the assessment methodology, but rather they illustrate the sensitivity of the system. The field staff must be well trained in order to minimize potential errors in differentiating between mortality and defoliation.

Individual Species Decline

The mean DI for individual tree species within each plot is summarized, for 1990 and 1989, in Tables 7 and 8, respectively. Variation in DI was considerable between species within plots and for similar species between plots. A summary of these data (averaged for each species across all plots) is given for 1986, 1987, 1989 and 1990 in Table 9. A summary of live, standing dead, fallen dead and missing trees for each species as of 1990 is provided in Table 10. Sugar maple constituted approximately 75% of all trees surveyed. Those species with the next highest proportion of total trees were white ash, red maple, beech, basswood and ironwood, all at approximately 3%. Fourteen of the 23 hardwood species present at the plots constituted less than 1% of all trees surveyed.

In general, those species having extreme DIs were those constituting less than 1% of the total trees assessed. American elm, for example, had a mean DI in 1990 of 59, and green ash had a mean DI (in 1989) of 0. Of those species representing a larger proportion of sampled trees, soft maple (3.1%) showed the largest relative decline in mean DI values between 1989 (18) and 1990 (23). Ironwood (2.7%) exhibited the second highest decline from 31 in 1989 to 35 in 1990. Ironwood showed more decline in 1989 and 1990 than in 1987 or 1986. Sugar maple, representing 75% of the total population, had a mean DI of

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bf	Bn	Bw	By	Cb	Ce	Cr
1	4									36				
2	8										5	21		
3	11									53	40			
4	12	31								12	13	54		
5	7	0					6	60			1			
6	12	10					2				15			
7	14	15			3	5	5							
8	7	7	50	12	12	15	53				0	13		
9	6				5	20				11				
10	8				2	10				100				
11	8					7								
12	5	14				7	0					6		
13	16									3	19		30	20
14	9					6	11							
15	10	10						0			1			
16	13	28			12					69				
17	25	16			95	100						38		
18	14	14				8				50	4			
19	8	5					5							
20	10			1	1	35	23				1			
21	4						11				1			
22	6				4	2				5				
23	7	4				1					4	24		
24	8	5	20		5	16	7				9	24		
25	3				22	24	13			10				
26	9		16		9	13				49				
27	8	30								65				
28	15	15								47				
29	13	26								100				
30	23		19							60	25			
31	16	19								36				
32	9	21			35					6				
33	9	15						15			32		1	
34	15	15			26									
35	10	19									17			
36	6				8					48	0		0	
37	28	34						0			2			
38	22	40				11	2				5			
39	10										37		0	70
40	3	11						18			6		0	

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bf	Bn	Bw	By	Cb	Ce	Cr
41	12				3	100			3					
42	3				18		4					10		
43	7				31		0					8		
44	4													
45	14											44		
46	4				9	0					10	12		
47	9	68			27	15	16				15			
48	4		5		16		1							
49	6				3	5	22					9		
50	4	3			3		1				100	26		
51	7				8	5	5					11		
52	14	10			1	0	22			0				
53	3	13					0					50		
54	4				33	10	7		6					
55	8				4	0	4							
56	15					4	4							
57	11				6	7	9							
58	6				53	4								
59	13				36		47					10		
60	11	13			12	19						26		
61	20	100			31	8	5							
62	7					23					11			
63	8	100			17	19	11							
64	21	9			14	31					25			
65	39				9	18								
66	35	31			53	14					58			
67	12						15				32			
68	10					5	5					10		
69	1	6			6		5					1		
70	12	37			25							29		
71	18				5	26	3				13	9		
72	6				7	63				57				
73	16	11				8	2							
74	11	10			12	11	64							
75	3	7			6	31	34			100		7		
76	22				12	9						15		
77	4				15	1						25		
78	13				15	6						11		
79	12						11				77			
80	15	9			38		9				18			

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bf	Bn	Bw	By	Cb	Ce	Cr
81	12					16	4				10			
82	19				20	24								
83	9				5	23	39				8			
84	7				11		24			62		13		
85	6				10	7			8					
86	7				16	18	5		25	31				
87	9													
88	6		7		11	42				23				
89	11	8			5	40				100		1		
90	12	1				14					16			
91	17					2					5	9		
92	10													
93	8				43	9				78				
94	10	33								21			20	
95														
96	14										12			
97	12						5							
98	14	17												
99	15						9				5			
100	17					16	5			100	25			
101	12	100					3				6	25		
102	6				18					35				
103	11				20	75	18							
104	11		16			1					4			
105	14													
106	11					32				51				
107	19									69	0			
108	9		33											
109	5							27						
110	6	11							1					

[1] Plot locations as shown on Figure 1.

[2] Species names as given on Table 9.

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Hl	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
1									19	11					
2															
3					29										
4															
5			5												
6															
7			1				15								
8	51				5										
9					1		17				5				
10					3		20		15		5				
11				1	10										
12															
13													5		
14	10		11												
15															
16															
17					5		9								
18			5						18			0	23		
19															
20					100										
21			17		11										
22			0				13								
23					37										
24			3												
25					18		45								
26									31						
27					1										
28									23						
29					27		24				45				
30							32								
31															
32					17		20				27	5	100		
33					22		8		10			10	1		
34					58		22								
35			100		1										
36															
37			20				20								
38															
39					20								40		
40					38								0		

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Hl	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
41	100						23	100							
42															
43		0			15		20								
44		3					6	5							
45		8					14								
46		2	11												
47															
48															
49		4				27									
50		2					0								
51		19					10							1	21
52		25													
53					40		13					25			
54		10			10		100								
55	100	1													
56															
57							22								
58		3	0				5	5							
59					17		23	11							
60		6			100										
61					6										
62					63										
63			20		20		16								
64									65						
65					37		60								
66			5		66							3			
67															
68		20													
69											37				
70		24			18	1									
71					10										
72							11								
73			8												
74															
75			8				16								
76															
77									55						
78															
79			53												
80			12		23										

TABLE 7: 1990 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Hi	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
81					29										
82							6								
83		11			10		5								
84					100						31				
85															
86				4	11				26						
87															
88					53				8						20
89			3		100		25								
90			1		16										
91					51										
92	30				77										
93							18								
94					7				19						
95															
96															
97															
98															
99					100				0						
100			6		100		20								
101							21		15						
102			100		5		22		59						
103					20										
104			16												
105															
106					100		25								
107			100												
108															
109									1	15					
110									8						

[1] Plot locations as shown on Figure 1.

[2] Species names as given on Table 2.

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bl	Bn	Bw	By	Cb	Ce	Cr
1	10									9				
2	10										10	27		
3	12									51	31			
4	11	33								5	3	68		
5	15	12					11	40			22			
6	8	0					0				0			
7	6	20			0	4	0							
8	2	2	0	1	2	12	50				0	3		
9	4				0	3				5				
10	4				0	4				0				
11	9					7								
12	4	14				3	0					0		
13	12									0	19		10	4
14	6					0	0							
15	7	10						0			0			
16	10	22			8					23				
17	23	36			86	100						33		
18	29	18				30		30		17	10			
19	11	0			0		0							
20	4			0	1	43	13				0			
21	7						7				0			
22	2				0	5				0				
23	4	2				0				100	0	30		
24	3	0	7		0	0	0				10	29		
25	1				11	12	6			0				
26	9		2		4	9				6				
27	6	18								49	0			
28	29	31								52				
29	20	30								100				
30	31		56							44	39			
31	25	21								30				
32	13	20			27					0				
33	13	23						0			24		0	
34	19	8			25									
35	13	26									24			
36	10				22					29			100	
37	23	30						0			4			
38	14	34				11	4				10			
39	6										36		0	21
40	4	24						15			5		0	

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bf	Bn	Bw	By	Cb	Ce	Cr
41	14				8	100			1					
42	2				10		2					10		
43	11				10		0					4		
44	4													
45	12											47		
46	3				2	5					0	14		
47	7	55			7	0	7				0			
48	6		0		15		0							
49	2				6		17					5		
50	9	37			0		0				100	37		
51	2					20	0							
52	11	4			0	0	30			0				
53	1	6					1					2		
54	2				27	10	0		11					
55	7					2	0							
56	13					5	0							
57	8				0	40	3							
58	6				59	7								
59	10	2			13		32					0		
60	4	7			0	1						20		
61	16				26	17	10							
62	2					13					7			
63	11				19	28	12							
64	16	17			25	30					10			
65	28				21	61								
66	25	40			10	18					55			
67	10						23				82			
68	1					1	1					1		
69	0	2			6		0					0		
70	9	8			20							16		
71	11				3	20	3				10	4		
72	9				45	54				45				
73	15	10				10	20							
74	7	1			10	12	34							
75	2	1			7	5	26			60		5		
76	21				8		4					10		
77	1				1	1						1		
78	11				6	0						10		
79	7						10				50			
80	7	11			40		1				0			

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]													
	Mh	Ms	Ab	Ag	Aw	Bd	Be	Bf	Bn	Bw	By	Cb	Ce	Cr
81	5					6	22				0			
82	9				11	10								
83	5				10	14	25				5			
84	2				0		16			59		0		
85	1				0	5			10					
86	7				10	3	2		31	0				
87	8													
88	1		1		1	3				3				
89	15	20			21	63						0		
90	16	20				27					29			
91	24					10					67	23		
92	18													
93	9				42	18				76				
94	7	21								17			2	
95	19				22					36			20	
96	10										10			
97	12						3							
98	14	18												
99	18						11				10			
100	12					5	2			100	26			
101	21	60					14				20	23		
102	3				4					25				
103	4				20	53	13							
104	17		22			1				17	3			
105	4													
106	14					37				75				
107	23									30	0			
108	7		26											
109	8							3						
110	5	2								1				

[1] Plot locations as shown on Figure 1.

[2] Species names as given on Table 9.

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Ill	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
1									23	8					
2															
3					34										
4															
5			20												
6															
7			0				20								
8	50				0										
9					0		7		0						
10					1		16		20		0				
11				10.5	5										
12															
13													0		
14	0		1												
15															
16															
17					30		37								
18			10		0				27			5	0		
19															
20					100										
21			30		57										
22			0				0								
23					30										
24			15												
25					28		42								
26									35						
27					0										
28									31						
29					48		44		87						
30							45								
31															
32					15		31				30	0	100		
33					29		21		30			2	0		
34					49		25								
35			100		20										
36															
37			30				31								
38										100					
39					10								37		
40					3								3		

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Hi	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
41	100						61	100							
42															
43		0			0		20								
44		11					15	10							
45		6					14								
46		1	10												
47															
48															
49		5				20									
50		14					0								
51		15					10							0	20
52			50												
53		1			2		6					1			
54		0			0										
55	100	0					100								
56															
57							17								
58		5	0				9	6							
59					3		20	10							
60		10			100										
61					12										
62					38										
63			30		54			30							
64									46						
65					24		63								
66			10		30							5			
67															
68		1													
69											41				
70		19			10										
71					10										
72							27								
73			16			0									
74															
75			0				10								
76															
77									1						
78															
79			50												
80			15		13										

TABLE 8: 1989 MEAN DECLINE INDEX (DI) FOR INDIVIDUAL SPECIES WITHIN EACH PLOT

Plot No.[1]	Species[2]														
	Ew	Hb	He	Hi	I	Ob	Or	Ow	Po	Pob	Pol	Pw	Sw	Tx	Ww
81					15										
82							0								
83		4			7		0								
84					100				53						
85	21														
86				0	3				16						
87															
88					2				1						22
89			5		75		39								
90			10		24										
91					60										
92	30				83										
93							3								
94					2				13						
95							50								
96															
97															
98			20												
99					100				30			20			
100			1		100		10								
101							39		3						
102			100		0		1		27						
103					18										
104			9												
105															
106					100		10								
107			100												
108															
109									0	19					
110									4						

[1] Plot locations as shown on Figure 1.

[2] Species names as given on Table 9.

TABLE 9: SUMMARY OF MEAN DECLINE INDEX FOR TREES SURVEYED

Species		% of Survey Population	Mean DI 1990	Mean DI 1989	Mean DI 1987	Mean DI 1986	Mean DI Change[1]
Hardwood Species							
Mh	Sugar Maple	74.7	11	10	14	12	-1
Aw	White Ash	3.6	17	13	18	17	0
Ms	Soft (red) Maple	3.1	23	18	24	22	1
Be	Beech	3.1	13	9	13	13	0
Bd	Basswood	3.0	19	18	21	18	1
I	Ironwood	2.7	35	31	22	23	12
By	Yellow Birch	1.7	17	18	24	20	-3
Cb	Black Cherry	1.6	19	15	30	28	-9
Or	Red Oak	1.4	21	24	17	20	1
Bw	White Birch	0.98	48	31	26	24	-24
Hb	Bitternut Hickory	0.85	10	6	15	14	-4
Po	Trembling Aspen	0.79	24	23	25	25	-1
Ab	Black Ash	0.38	21	14	21	12	-9
Pob	Balsam Poplar	0.15	13	42	29	23	-10
Pol	Largetooth Aspen	0.14	25	24	23	36	-11
Ew	American Elm	0.11	59	50	NR[2]	53	6
Bn	Butternut	0.07	9	13	17	27	-18
Cr	Pin Cherry	0.06	45	12	15	12	33
Ow	White Oak	0.05	31	31	51	42	-11
Hi	Hickory	0.03	3	5	3	10	-7
Ob	Bur Oak	0.02	14	10	31	33	-19
Ag	Green Ash	0.02	7	0	NR	8	-1
Ww	Weeping Willow	0.02	21	21	32	28	-7
Conifer Species							
He	Hemlock	0.81	NA[3]	NA	NA	NA	
Bf	Balsam Fir	0.25	NA	NA	NA	NA	
Pw	White Pine	0.18	NA	NA	NA	NA	
Ce	White Cedar	0.13	NA	NA	NA	NA	
Sw	White Spruce	0.07	NA	NA	NA	NA	
Tx	Larch	0.01	NA	NA	NA	NA	

[1] Change in mean DI in 1990 relative to 1986.
[2] NR = not recorded.
[3] NA = not available for conifers.

TABLE 10: 1990 STAND COMPOSITION STATISTICS

Species		Total No. Trees	No. Live Trees	No. Standing Dead Trees	No. Fallen Dead Trees	No. Missing Trees
Hardwood Species						
Mh	Sugar Maple	8,143	7,715	341	79	8
Aw	White Ash	393	362	19	12	-
Ms	Soft (red) Maple	335	314	17	4	-
Be	Beech	334	318	10	6	-
Bd	Basswood	331	296	25	10	-
I	Ironwood	294	230	46	18	-
By	Yellow Birch	180	159	17	4	-
Cb	Black Cherry	175	150	19	6	-
Or	Red Oak	158	152	5	1	-
Bw	White Birch	107	76	30	1	-
Hb	Bitternut Hickory	93	88	3	2	-
Po	Trembling Aspen	86	79	5	2	-
Ab	Black Ash	41	37	2	2	-
Pob	Balsam Poplar	16	15	-	1	-
Pol	Largetooth Aspen	15	12	1	2	-
Ew	American Elm	12	5	6	1	-
Bn	Butternut	8	6	2	-	-
Cr	Pin Cherry	6	6	-	-	-
Ow	White Oak	5	4	1	-	-
Hi	Hickory	3	3	-	-	-
Ob	Bur Oak	2	2	-	-	-
Ag	Green Ash	2	2	-	-	-
Ww	Weeping Willow	2	2	-	-	-
Conifer Species						
He	Hemlock	89	78	8	3	-
Bf	Balsam Fir	27	19	3	5	-
Pw	White Pine	20	16	2	2	-
Ce	White Cedar	14	12	-	2	-
Sw	White Spruce	8	7	1	-	-
Tx	Larch	1	1	-	-	-
TOTALS		10,900	10,166	563	163	8

11 in 1990, 10 in 1989, 14 in 1987 and 12 in 1986. These changes compare well with the above-mentioned discussion of increased decline from 1986 to 1987; improved health from 1987 to 1989, and minimal change between 1989 and 1990. Similar relationships are also evident for some of the other species, i.e., basswood and yellow birch.

Mean values of individual decline attributes and tree quality observations are listed, for each plot in 1990 and 1989, in Tables 11 and 12. This information may be useful for assessing potential causes of decline on a plot-by-plot basis.

<u>Tree Mortality</u>

Tree mortality data for the survey plots are summarized by year for 1986, 1987, 1989 and 1990 in Table 13. Tree mortality across all survey plots was 1.7% in 1986, 3.1% in 1987, 1.1% in 1989 and 1.5% in 1990. The total number of dead trees increased from 1986 to 1987, and from 1989 to 1990. The number of dead trees in 1986 was also higher than in 1989 and 1990. Of concern is that the number of dead trees apparently decreased from 1987 to 1989. In this time period there was a considerable decrease in the number of dead sugar maple. Since the same trees were surveyed each year, it is probable that many of the trees noted to be dead in 1987 were extensively defoliated. This would explain the apparent recovery of a large number of trees in 1989. In view of this, there is some question about the validity of the 1987 mortality data.

Tree species mortality data for the 1989 and 1990 survey years are summarized by plot and MNR District in Tables 14 and 15, respectively. In total, 70 sugar maple were dead in 1989, and 79 were fallen dead in 1990. Almost one-quarter of the dead sugar maple identified in the 1989 survey were found in the Minden District. The Parry Sound and Espanola Districts each contained roughly 10% of the total 1989 dead sugar maple. The remaining dead maple were scattered in small numbers throughout the rest of the Province. In 1990, dead sugar maple were more evenly distributed across the Province. Aylmer District had the highest percentage of dead maple within Ontario at 8.9%. The North Bay and Niagara Districts both had the next highest percentage at 7.9%.

TABLE 11: SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT (1990)

Plot	% Dead Branches	% Slight Chlorosis	% Strong Chlorosis	% Undersized Leaves	Decline Index	Crown Class Ratio	% Early Fall Colour	% Necrosis	% Defoliation	Broken Stems	Wounds	Frost Cracks (Minor)	Frost Cracks (Major)	Cracks (Total)	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location 1	Sprout Abundance 1	Sprout Location 2	Sprout Abundance 2	Bark Sloughing	Nails in Tree	Broken Secondary Stems
1	7	3	0	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
2	12	1	0	1	13	4	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
3	18	1	0	1	18	4	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
4	15	2	0	2	16	4	0	0	2	0	0	1	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0
5	6	2	0	1	7	3	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
6	11	2	0	0	11	4	0	0	1	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
7	11	5	1	1	12	4	0	0	1	0	1	0	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
8	12	5	1	0	13	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
9	8	2	0	2	9	3	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
10	10	4	2	0	11	3	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0
11	7	6	2	1	8	3	0	0	3	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
12	6	2	1	0	6	3	1	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
13	16	3	0	0	16	4	1	0	1	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
14	8	4	1	0	9	3	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
15	9	1	1	0	9	3	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
16	19	3	0	3	20	4	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
17	22	7	1	3	24	4	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18	13	5	2	0	14	4	1	0	8	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
19	7	2	0	1	7	3	0	0	0	0	0	0	1	1	4	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0
20	12	4	0	1	13	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
21	5	1	0	1	6	3	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
22	6	2	0	1	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
23	8	1	0	1	9	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
24	10	5	1	0	10	3	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
25	12	1	0	0	12	3	0	0	3	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
26	12	1	0	3	12	4	0	0	1	0	1	1	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	1	0
27	17	3	1	2	18	4	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
28	17	9	1	2	19	4	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
29	17	4	1	0	18	6	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	21	12	8	1	25	4	1	0	21	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
31	15	15	6	1	18	4	0	1	7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
32	13	2	0	1	14	4	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
33	12	3	1	2	13	4	0	0	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
34	19	5	2	1	20	4	3	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
35	13	6	1	1	14	4	1	0	2	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
36	9	0	0	0	9	3	0	0	8	0	1	0	1	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
37	24	4	0	0	24	4	0	5	4	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

TABLE 11: SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT (1990)

Plot	% Dead Branches	% Slight Chlorosis	% Strong Chlorosis	% Undersized Leaves	Decline Index	Crown Class Ratio	% Early Fall Colour	% Necrosis	% Defoliation	Broken Stems	Wounds	Frost Cracks (Minor)	Frost Cracks (Major)	Cracks (Total)	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location 1	Sprout Abundance 1	Sprout Location 2	Sprout Abundance 2	Bark Sloughing	Nails in Tree	Broken Secondary Stems
38	21	4	5	0	23	4	0	0	8	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
39	14	2	0	0	15	4	0	0	1	0	0	0	1	1	0	0	0	1	1	0	1	0	0	1	0	0	0	0	1	0
40	8	0	0	0	8	6	0	3	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
41	16	5	1	2	17	4	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	3	0	0	0	3	3	0	0	4	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
43	7	2	0	3	8	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
44	3	2	0	1	4	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	13	3	0	4	14	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
46	6	0	0	0	6	3	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
47	12	0	0	0	12	4	0	1	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
48	6	0	0	0	6	3	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
49	6	2	0	1	7	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
50	8	0	0	0	8	4	0	0	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
51	7	1	0	0	8	3	0	0	2	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
52	12	2	0	3	13	4	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
53	5	2	0	3	6	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	6	3	1	0	7	3	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
55	8	4	0	1	9	3	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
56	14	1	0	2	15	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
57	10	4	1	0	11	3	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0
58	10	2	0	1	10	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	14	8	2	0	16	4	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
60	12	6	2	0	13	4	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
61	21	4	0	0	21	4	0	0	6	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
62	12	4	1	0	13	4	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	0	0	0	0
63	12	5	1	0	13	4	0	1	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
64	21	5	2	1	22	4	0	0	14	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
65	33	6	2	3	34	5	0	0	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
66	34	7	2	2	35	5	0	1	7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
67	12	4	1	0	13	4	0	0	6	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
68	10	0	0	0	10	3	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
69	4	0	1	0	4	3	0	0	3	0	1	0	1	1	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0
70	15	0	0	0	15	4	0	0	4	0	1	0	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0
71	16	2	0	0	17	4	0	0	4	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
72	9	14	0	2	11	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
73	13	9	3	0	15	4	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
74	11	5	2	0	12	4	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0

TABLE 11: SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT (1990)

Plot	% Dead Branches	% Slight Chlorosis	% Strong Chlorosis	% Undersized Leaves	Decline Index	Crown Class Ratio	% Early Fall Colour	% Necrosis	% Defoliation	Broken Stems	Wounds	Frost Cracks (Minor)	Frost Cracks (Major)	Cracks (Total)	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location 1	Sprout Abundance 1	Sprout Location 2	Sprout Abundance 2	Bark Sloughing	Nails in Tree	Broken Secondary Stems
75	10	5	2	0	11	4	0	0	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
76	18	0	0	0	18	4	0	0	4	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
77	14	0	0	1	14	3	0	1	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
78	12	0	0	0	13	3	0	0	4	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
79	13	2	0	0	13	4	0	0	8	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
80	15	3	0	1	16	4	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
81	18	3	1	0	19	4	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
82	17	8	3	1	19	4	0	0	7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
83	10	4	1	0	11	4	0	0	6	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
84	12	1	0	2	13	4	0	0	3	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
85	6	4	1	1	7	3	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
86	9	3	0	0	10	3	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
87	9	1	0	0	9	3	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
88	14	0	0	0	14	3	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
89	14	2	0	1	15	4	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
90	12	3	0	0	12	4	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	18	6	1	2	19	4	1	1	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
92	12	4	0	2	13	4	0	0	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
93	12	1	0	0	12	4	0	0	12	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
94	13	1	0	0	13	3	0	1	6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
96	13	3	1	0	14	4	0	0	3	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
97	11	4	1	0	11	4	0	0	4	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
98	14	3	0	0	14	4	0	0	3	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
99	15	4	0	0	15	4	0	0	5	0	1	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
100	15	4	1	0	16	4	0	0	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
101	12	3	0	0	12	4	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
102	11	1	0	1	11	3	0	0	3	0	1	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0
103	14	5	0	1	15	4	0	0	3	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
104	10	8	0	1	11	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
105	13	6	1	0	14	4	0	0	5	0	1	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0
106	17	8	1	0	18	4	0	0	17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
107	20	9	1	2	21	4	1	0	13	0	1	0	1	1	0	0	0	0	1	0	0	0	0	2	1	0	0	0	0	0
108	11	1	0	0	11	3	0	0	1	0	0	1	1	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0
109	6	1	0	0	7	3	0	0	0	0	0	0	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
110	6	0	0	1	7	3	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

TABLE 12: SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT (1989)

Plot Number	% Dead Branches	% Slight Chlorosis	% Early Fall Colour	% Strong Chlorosis	% Necrosis	% Undersized Leaves	Crown Class Ratio	% Defoliation	Broken Stems	Wounds	Frost Cracks	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location	Sprout Abundance	Bark Sloughing	Nails in Tree
1	5.9	11.6	16.4	0.3	0.2	0.0	2.5	20.1	0.0	0.4	0.2	0.0	0.0	0.1	0.1	0.1	0.9	0.0	0.0	0.0	1.1	0.9	0.3	2.0
2	12.5	9.8	8.9	0.3	0.0	0.0	3.0	15.9	0.0	0.2	0.4	0.0	0.0	0.1	0.0	0.2	0.5	0.0	0.0	0.1	1.3	0.6	-0.7	2.0
3	14.7	3.5	11.2	0.0	0.6	0.1	3.2	3.0	0.0	0.4	0.3	0.0	0.0	0.0	0.2	0.3	0.5	0.0	0.0	0.0	1.3	0.7	0.4	2.0
4	13.6	9.8	6.6	0.2	0.4	0.1	3.1	1.5	0.0	0.2	0.3	0.0	0.0	0.1	0.3	0.1	0.8	0.0	0.1	0.0	1.3	0.7	0.6	2.0
5	13.1	8.6	2.6	1.0	0.8	0.2	3.2	4.1	0.0	0.7	0.5	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.1	0.1	1.0	0.6	0.0	0.0
6	7.4	1.4	0.2	0.0	1.2	0.4	2.6	2.5	0.0	0.3	0.4	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.4	0.0	2.3	0.9	0.6	1.0
7	5.6	0.7	0.2	0.0	1.2	0.4	2.5	1.5	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.6	0.1	1.9	0.9	0.7	1.0
8	5.7	2.2	0.3	0.0	0.1	1.2	2.5	3.5	0.0	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	1.7	0.7	0.2	1.0
9	3.7	0.3	0.3	0.1	0.6	1.3	2.3	3.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	1.7	0.9	0.4	1.0
10	5.6	1.4	0.2	0.6	0.2	0.3	2.5	3.8	0.0	0.3	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.8	0.9	0.6	1.0
11	7.2	0.1	0.1	0.6	0.1	0.1	2.6	14.5	0.1	0.4	0.4	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.1	0.0	2.3	1.0	0.5	1.0
12	4.7	0.7	0.0	0.1	0.6	0.2	2.4	1.9	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	1.3	0.9	0.2	1.0
13	11.0	4.0	0.3	0.0	1.5	1.5	2.9	10.1	0.2	0.7	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1	1.1	0.6	0.0	0.0
14	4.6	2.2	0.2	0.1	0.2	0.0	2.3	2.6	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.0	1.7	0.9	0.3	1.0
15	5.9	1.9	0.3	0.0	0.3	2.2	2.6	4.2	0.0	0.4	0.2	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.1	1.5	0.7	0.0	0.0
16	12.1	1.0	0.5	0.5	0.3	5.0	3.9	14.0	0.1	0.3	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	1.3	0.6	0.0	1.0
17	24.2	11.6	9.7	9.2	2.7	0.6	4.1	7.9	0.0	0.6	0.5	0.0	0.0	0.0	0.1	0.3	0.3	0.0	0.0	0.1	1.3	0.6	0.1	0.0
18	16.9	1.9	0.1	0.0	1.5	1.5	3.5	0.4	0.0	0.6	0.6	0.0	0.0	0.1	0.1	0.3	0.3	0.0	0.0	0.1	1.3	0.6	0.0	0.0
19	10.2	1.1	0.8	0.0	0.6	0.3	3.1	0.3	0.2	0.3	0.1	3.8	5.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.2	0.6	0.0	1.0
20	7.9	0.4	0.1	0.0	0.2	0.0	3.0	0.0	0.1	0.4	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.0	0.1	2.0	1.0	0.0	1.0
21	8.9	0.1	0.3	0.0	0.5	0.0	2.8	0.1	0.1	0.4	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	1.7	0.7	0.1	1.0
22	2.0	0.0	0.0	0.0	1.0	0.0	3.2	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.5	1.1	0.0	1.0
23	8.0	0.2	0.3	0.1	0.7	0.0	2.9	3.2	0.1	0.6	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	1.7	0.9	0.0	1.0
24	7.6	0.0	0.0	0.0	0.5	0.3	2.8	2.7	0.1	0.5	0.2	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	1.6	0.9	0.0	1.0
25	7.1	2.1	0.5	0.1	0.2	0.1	3.9	21.0	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.8	0.0	0.7
26	8.0	3.9	1.6	0.1	0.5	2.5	4.1	28.2	0.2	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	0.8	0.0	1.0
27	12.7	0.7	0.0	0.2	0.2	0.0	3.3	5.2	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.0	0.0	1.0
28	24.4	35.4	18.1	9.6	0.1	2.6	4.1	24.8	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.1	1.0	0.5	0.0	0.0
29	25.5	9.9	2.4	0.5	0.3	0.1	4.1	3.4	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	1.2	0.6	0.0	0.0
30	31.0	14.5	5.7	0.0	0.8	0.0	4.8	14.4	0.3	0.5	0.3	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	1.3	0.9	0.0	1.0
31	13.2	23.9	41.0	15.8	0.4	0.0	3.4	36.8	0.0	0.8	0.4	0.0	0.0	0.0	0.1	0.6	0.3	0.0	0.0	0.2	1.1	0.6	0.0	0.0
32	15.0	12.4	1.5	0.0	0.6	1.0	3.4	6.3	0.0	0.1	0.4	0.0	0.0	0.2	0.1	0.4	0.4	0.0	0.0	0.1	1.0	0.5	0.0	0.0
33	14.4	8.7	3.8	0.0	1.5	1.8	3.2	7.0	0.0	0.4	0.2	0.0	0.0	0.1	0.1	0.6	0.4	0.0	0.0	0.0	1.2	0.6	0.0	0.0
34	20.3	5.2	4.6	3.7	1.3	3.7	3.8	53.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.8	0.4	0.0	1.0
35	16.3	7.9	2.8	0.5	0.2	2.1	3.6	10.3	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	1.1	0.5	0.0	1.0
36	11.1	11.5	0.8	0.2	1.4	3.2	2.9	2.2	0.1	0.4	0.4	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0	0.1	1.2	0.6	0.1	[illegible]
37	20.1	9.0	3.2	0.3	4.0	1.4	3.8	11.3	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.9	0.5	0.1	0.0
38	15.9	4.3	1.6	0.0	3.7	0.6	3.2	12.4	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.0
39	10.6	3.6	0.6	0.0	0.5	0.6	2.9	8.1	0.1	0.3	0.4	0.0	0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.1	0.9	0.4	0.0	0.0
40	6.6	0.7	0.2	0.0	3.0	4.1	2.8	8.4	0.1	0.3	0.5	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.1	0.6	0.3	0.0	0.0
41	17.7	7.1	2.2	0.0	6.0	0.0	4.5	7.4	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	0.4	0.1	1.0
42	1.9	0.5	0.0	0.4	0.2	0.1	2.2	0.7	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	2.1	0.8	0.0	0.0
43	9.8	0.3	0.2	0.1	0.5	0.3	3.9	11.3	0.1	0.8	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.5	1.4	0.7	0.0	1.0
44	5.8	1.1	0.6	0.1	0.0	[illegible]	[illegible]	[illegible]	0.1	0.4	0.0	0.0	0.0	[illegible]	[illegible]	0.1	0.1	0.0	0.0	0.1	2.0	1.2	0.0	1.0
45	11.8	1.5	0.6	0.0	0.1	2.6	3.3	1.4	0.1	0.4	0.1	0.0	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.2	1.5	1.0	0.1	1.0
46	4.2	1.0	0.3	0.0	0.1	1.3	2.4	2.7	0.0	0.3	0.1	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.1	1.7	0.9	0.0	0.0
47	7.4	0.1	0.0	0.0	0.2	0.8	2.6	1.2	0.0	0.7	0.1	0.5	0.5	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.5	0.7	0.1	0.0
48	7.4	0.0	0.1	0.0	0.1	0.0	2.6	1.0	0.0	0.3	0.1	0.1	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0	1.5	0.8	0.0	0.0
49	3.6	0.5	0.1	0.0	1.3	0.2	3.4	9.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.1	0.0	[illegible]

TABLE 12: (Cont'd) SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT (1989)

Plot Number	% Dead Branches	% Slight Chlorosis	% Early Fall Colour	% Strong Chlorosis	% Necrosis	% Undersized Leaves	Crown Class Ratio	% Defoliation	Broken Stems	Wounds	Frost Cracks	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location	Sprout Abundance	Bark Sloughing	Nails In Tree
50	14.9	0.2	0.0	0.0	0.3	0.0	3.4	2.1	0.1	0.6	0.1	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.3	1.7	1.0	0.1	1.0
51	4.3	0.0	0.0	0.1	0.0	0.0	2.3	0.7	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	1.7	0.9	0.0	0.0
52	10.5	0.6	0.0	0.0	1.4	0.0	2.9	0.4	0.1	0.4	0.3	0.4	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.1	1.5	0.6	0.0	0.3
53	9.4	0.8	0.4	0.1	0.9	0.0	3.3	5.1	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	1.7	1.1	0.0	1.0
54	3.5	0.4	0.1	0.3	0.5	0.1	2.3	2.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	1.9	0.9	0.4	1.0
55	9.0	1.3	0.0	0.0	0.6	0.0	3.7	9.6	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	1.4	0.7	0.0	1.0
56	12.5	0.4	0.1	0.0	0.1	0.0	4.4	14.6	0.1	0.6	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	1.4	0.9	0.1	1.0
57	8.0	0.5	0.7	0.3	0.2	0.0	3.3	1.0	0.0	0.3	0.1	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.1	0.0	1.5	1.0	0.6	1.0
58	10.6	5.2	1.2	0.2	0.1	0.0	3.9	9.2	0.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	0.9	0.0	1.0
59	9.9	0.0	0.0	0.1	0.2	1.9	2.8	4.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.3	1.0	0.3	1.0
60	5.5	0.5	0.3	0.2	0.4	0.6	2.5	1.7	0.0	1.0	0.1	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.0	1.4	1.0	0.6	1.0
61	15.8	8.3	0.2	0.0	3.9	0.2	3.4	1.8	0.0	0.2	0.3	0.0	0.0	0.1	0.1	0.2	0.4	0.0	0.1	0.0	0.7	0.4	0.0	0.0
62	6.1	2.6	1.1	2.1	0.4	0.0	2.7	0.9	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.5	0.0	0.1	0.0	2.0	0.9	0.6	0.1
63	16.8	8.5	0.6	0.2	0.9	1.1	3.5	3.4	0.0	0.3	0.2	0.0	0.0	0.1	0.0	0.2	0.2	0.0	0.1	0.1	0.8	0.4	0.0	0.0
64	16.5	7.2	1.3	0.9	1.3	0.0	3.5	1.6	0.0	0.5	0.5	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.9	0.4	0.0	0.0
65	23.8	13.5	12.3	10.5	4.1	0.7	4.0	8.3	0.0	0.3	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.0	0.0	0.0	0.7	0.4	0.0	0.0
66	22.7	14.0	2.5	0.0	2.0	0.8	3.9	13.1	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.6	0.4	0.0	0.0
67	13.1	8.1	0.7	0.3	2.0	1.5	3.2	1.1	0.0	0.4	0.5	0.0	0.0	0.0	0.1	0.3	0.4	0.0	0.0	0.1	0.8	0.4	0.0	0.0
68	4.2	0.4	0.0	0.0	0.1	1.1	2.4	1.4	0.0	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.3	0.7	0.0	0.0
69	3.3	1.2	0.1	0.3	0.0	0.0	2.3	0.4	0.0	0.8	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	1.6	0.9	0.0	0.0
70	10.0	0.2	0.0	0.1	0.2	1.8	2.8	2.8	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	1.3	0.6	0.0	0.0
71	9.9	0.8	0.4	0.0	0.9	0.0	3.3	5.8	0.2	1.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	1.6	1.1	0.0	0.0
72	15.9	8.0	0.1	0.0	0.2	1.2	3.5	5.6	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.8	0.4	0.0	0.0	0.0
73	11.9	18.9	0.9	0.3	2.2	2.9	3.1	6.6	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.2	0.1	0.5	0.3	0.0	0.0
74	7.8	3.7	0.6	0.1	2.3	0.0	2.8	0.8	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.8	0.4	0.0	0.0
75	6.4	0.5	0.3	0.0	1.1	0.0	2.9	3.0	0.0	0.6	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	1.7	0.7	0.0	1.0
76	16.0	0.0	0.0	0.0	0.1	0.4	3.3	1.4	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1	1.4	0.7	0.0	0.0
77	7.5	0.0	0.0	0.0	0.1	1.2	2.6	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.5	0.7	0.1	0.0
78	9.8	0.9	0.2	0.1	0.0	0.4	2.8	2.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.6	0.9	0.0	0.0
79	9.1	0.1	0.1	0.1	0.2	0.1	2.8	1.1	0.0	0.4	0.2	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.1	0.0	1.6	1.0	0.4	1.0
80	8.6	0.3	0.3	0.4	1.4	0.4	2.7	6.5	0.1	0.2	0.2	0.0	0.0	0.2	0.0	0.2	0.3	0.0	0.1	0.0	1.6	0.9	0.4	1.0
81	9.9	0.4	1.3	0.5	0.3	0.1	2.8	12.3	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	2.0	0.9	0.4	1.0
82	9.0	0.0	0.0	0.0	0.5	0.7	2.8	4.6	0.0	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.7	0.0	0.1	0.0	1.8	0.9	0.3	1.0
83	6.4	0.2	0.1	0.0	0.1	0.0	2.5	4.1	0.0	0.5	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0.0	2.1	1.0	0.6	1.0
85	8.1	0.9	0.0	0.0	0.3	1.6	2.6	1.8	0.1	0.7	0.2	0.0	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.1	1.8	0.8	0.0	0.0
85	1.5	3.8	0.4	0.0	0.1	0.0	2.2	12.3	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.1	2.1	1.1	0.0	0.0
86	6.0	0.0	0.1	0.0	1.2	0.0	2.4	8.1	0.0	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.2	0.0	1.8	1.0	0.4	1.0
87	7.9	0.6	0.0	0.0	0.2	0.2	2.7	0.4	0.0	0.3	[illegible]	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.1	1.9	0.9	0.0	0.0
88	10.3	0.5	0.2	0.0	1.6	6.7	2.8	2.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.2	0.8	0.0	0.0
89	16.8	10.1	2.0	0.4	1.2	0.0	3.4	3.6	0.0	0.5	0.4	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0	0.1	1.5	0.8	0.1	0.4
90	17.3	9.6	1.7	0.3	0.3	0.5	3.6	8.5	0.0	0.6	0.7	0.0	0.0	0.0	0.2	0.4	0.4	0.0	0.0	0.1	0.8	0.4	0.0	0.4
91	24.9	7.3	0.3	0.0	1.1	0.0	4.0	0.7	0.0	0.6	0.6	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1	1.1	0.8	0.2	0.0
92	19.3	13.3	2.1	0.0	0.9	0.0	3.7	14.0	0.0	0.6	0.6	0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.1	1.0	0.5	0.0	0.0
93	11.2	2.3	3.6	0.0	0.4	0.5	2.9	23.8	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1	1.6	1.0	0.0	0.0
94	6.4	3.8	1.7	0.0	0.5	0.7	2.5	12.6	0.0	0.2	0.1	0.0	0.0	0.1	0.2	0.5	0.0	0.0	0.1	0.1	1.7	0.9	0.0	0.0
95	14.1	16.2	13.5	0.4	1.2	3.4	3.2	8.5	0.0	0.4	0.1	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.1	0.1	1.7	0.8	0.1	0.0
96	10.2	0.9	0.4	0.5	0.6	0.0	2.8	1.3	0.1	0.2	0.5	0.0	0.0	0.1	0.1	0.2	0.2	0.0	0.1	0.0	1.9	0.9	0.7	1.0
97	10.6	2.1	3.4	0.5	0.7	0.0	2.9	0.3	0.0	0.3	0.4	0.0	0.0	0.1	0.1	0.0	1.1	0.0	0.1	0.0	2.1	1.0	0.7	1.0
98	11.5	1.8	2.0	0.2	0.5	7.9	2.9	0.9	0.0	0.3	0.5	0.0	0.0	0.1	0.1	0.0	1.0	0.0	0.1	0.0	1.4	0.9	0.4	0.8
99	16.8	4.6	0.0	0.0	0.6	4.3	3.4	1.5	0.1	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.0	1.3	0.8	0.5	1.0

TABLE 12: SUMMARY OF MEAN TREE QUALITY OBSERVATIONS BY PLOT
(Cont'd) (1989)

Plot Number	% Dead Branches	% Slight Chlorosis	% Early Fall Colour	% Strong Chlorosis	% Necrosis	% Undersized Leaves	Crown Class Ratio	% Defoliation	Broken Stems	Wounds	Frost Cracks	Tap Holes Healed	Tap Holes Total	Other Holes	Fungal Structures	Cankers	Insect Injury	Other Wounds	Sugar Maple Borer	Swelling	Sprout Location	Sprout Abundance	Bark Sloughing	Nails in Tree
100	10.7	3.0	1.1	0.3	0.2	2.0	2.9	2.3	0.0	0.2	0.3	0.0	0.0	0.0	0.2	0.1	0.2	0.0	0.1	0.0	1.3	0.8	0.4	1.0
101	15.1	5.3	23.3	0.0	0.3	0.3	3.1	11.7	0.0	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.5	0.0	0.1	0.0	1.5	0.7	0.6	1.0
102	5.7	0.7	0.0	0.0	0.3	0.1	2.4	2.9	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.0	1.4	0.9	0.0	0.0
103	8.6	2.9	0.1	0.0	0.2	0.2	2.7	8.8	0.0	0.4	0.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.1	1.7	1.0	0.0	0.0
104	11.6	9.2	10.7	0.5	0.3	0.1	2.9	0.5	0.0	0.2	0.3	0.0	0.1	0.2	0.1	0.1	0.4	0.0	0.0	0.0	1.2	0.8	0.7	1.0
105	3.9	0.2	0.0	0.0	0.2	0.2	2.3	4.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	1.3	0.6	0.0	0.0
106	18.6	10.7	7.0	0.3	1.5	0.0	4.5	20.0	0.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.2	0.3	0.1
107	20.7	11.6	12.6	4.6	0.9	0.5	4.8	26.2	0.1	0.5	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.9	0.0	0.0
108	7.8	2.3	0.4	0.0	0.2	0.3	2.7	11.6	0.1	0.3	0.3	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	1.4	0.7	0.1	0.0
109	7.9	0.5	0.1	0.0	0.1	0.3	2.7	8.4	0.0	0.3	0.5	0.0	0.0	0.1	0.2	0.8	0.0	0.0	0.0	0.1	1.7	0.8	0.1	0.0
110	3.7	2.5	0.9	0.0	0.2	0.1	2.3	9.2	0.0	0.3	0.2	0.0	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.0	1.6	0.6	0.0	0.0
	10.97	4.31	2.41	0.64	0.80	0.84	3.09	6.89	0.04	0.38	0.20	0.05	0.06	0.05	0.06	0.17	0.17	0.00	0.04	0.07	1.40	0.76	0.15	0.53

TABLE 13: TREE MORTALITY BY SPECIES IN 1986, 1987, 1989 AND 1990[1]

Species	No. of Dead Trees 1986	1987	1989	1990[2]
Hardwood Species				
Sugar Maple	97	182	70	79
White Ash	16	22	9	12
Soft (red) Maple	9	15	3	4
Beech	2	4	3	6
Basswood	5	11	6	10
Ironwood	21	35	14	18
Yellow Birch	9	12	4	4
Black Cherry	13	17	2	6
Red Oak	3	4	1	1
White Birch	7	7	1	1
Bitternut Hickory	0	4	1	2
Trembling Aspen	4	4	0	2
Black Ash	0	1	0	2
Balsam Poplar	0	0	0	1
Largetooth Aspen	0	0	0	2
American Elm	0	0	1	1
Butternut	0	0	0	0
Pin Cherry	0	0	0	0
White Oak	0	0	0	0
Hickory	0	0	0	0
Bur Oak	0	0	0	0
Green Ash	0	0	0	0
Weeping Willow	0	0	0	0
TOTAL HARDWOODS	186	318	115	151
Conifer Species				
Hemlock	3	7	1	3
Balsam Fir	1	5	4	5
White Pine	0	2	2	2
White Cedar	1	1	3	2
White Spruce	0	3	0	0
Larch	0	0	0	0
TOTAL CONIFER	5	18	10	12
TOTAL (ALL SPECIES)	191	336	125	163
% MORTALITY	1.7%	3.1%	1.1%	1.5%

[1] Includes fallen dead trees only.
[2] Plot No. 95 not assessed in 1990, therefore, only 10,900 trees were assessed this year.

TABLE 14: A SUMMARY OF DEAD (FALLEN) TREES BY SURVEY PLOT IN 1989 AND 1990

Species	Plot	MNR District	Dead Tree No. (1989)	Dead Tree No. (1990)
Mh Sugar Maple	5	Bracebridge		48
	6	Cornwall		100
	7	Cornwall		37
	13	Sault Ste. Marie	77	77
	14	Cornwall		12, 39
	15	Wawa	42	42
	17	Parry Sound	9, 20, 46	87
	18	Parry Sound	56	55, 56, 70
	26	Sudbury	36, 54, 57	36, 54, 58, 67
	28	Sudbury	82	82
	29	Sudbury		16
	32	Blind River	68	
	34	Blind River		9
	35	Blind River	27	27
	36	Blind River	67, 75	21
	37	Sault Ste. Marie	72	72
	38	Sault Ste. Marie	64	58
	39	Sault Ste. Marie	43	43
	41	Niagara	46, 50, 63	38, 46, 50, 63
	43	Niagara		76
	45	Cambridge		97
	47	Aylmer		60
	48	Simcoe		31, 79
	50	Aylmer	21, 52	7, 15, 21, 50, 52
	51	Chatham	34	82
	58	Niagara	34	34
	61	Bancroft	52, 65, 68, 88	12
	63	Minden		72
	64	Minden	4, 35, 37, 40	
	65	Minden	5, 9, 36, 42, 44	44
	66	Minden	51, 60, 63, 80, 86, 88, 94, 97	27, 86
	68	Chatham		28
	69	Chatham		8
	70	Aylmer		55
	73	Lindsay	81	
	74	Lindsay	75, 76	21
	75	Maple		58
	79	Tweed	50, 69	37, 50, 69
	82	Napanee	15	
	84	Owen Sound	23	23, 98
	85	Owen Sound	3	3
	86	Brockville		34
	89	Parry Sound	12	

TABLE 14: A SUMMARY OF DEAD (FALLEN) TREES BY SURVEY PLOT IN 1989 AND 1990 (Cont'd)

Species	Plot	MNR District	Dead Tree No. (1989)	Dead Tree No. (1990)
	90	Parry Sound	59	
	91	Parry Sound	49, 67	49
	93	Espanola	42, 61, 92	27, 42, 92
	95	Espanola	68, 97, 99	
	96	Algonquin Park	12, 58, 68	12, 14
	97	Algonquin Park	22, 77	22, 77
	104	North Bay		6, 12, 24, 26, 98, 100
	105	Owen Sound	27	6, 27, 88
	106	Espanola		97
	107	Espanola	31	31
	108	Thunder Bay		81
	109	Thunder Bay		3, 15, 42
Aw White Ash	36	Blind River	49	
	48	Simcoe		67, 75, 76
	54	Brockville	50	50, 61
	61	Bancroft	78, 94	
	63	Minden	16	16
	65	Minden		53
	66	Minden	65	
	72	Lindsay		26
	76	Wingham	62	62
	82	Napanee		17
	83	Napanee	99	99
	93	Espanola	4	4
Ms Soft (red) Maple	16	Sudbury		55
	38	Sault Ste. Marie	96	96
	40	Sault Ste. Marie		18
	50	Aylmer		61
	61	Bancroft	83	
	63	Minden	7	
Be Beech	38	Sault Ste. Marie	46	46
	50	Aylmer	44	44
	67	Minden	89	38, 89
	81	Tweed		24
	99	Algonquin Park		82
Bd Basswood	8	Cornwall	21	21, 88
	22	Huronia		29
	51	Chatham		73
	66	Minden	28, 71, 72	28, 71, 72

TABLE 14: A SUMMARY OF DEAD (FALLEN) TREES BY SURVEY PLOT IN 1989 AND 1990 (Cont'd)

Species		Plot	MNR District	Dead Tree No. (1989)	Dead Tree No. (1990)
		93	Espanola	75	25, 26, 75
		103	Owen Sound	90	
I	Ironwood	18	Parry Sound		70
		20	Huronia	35	35, 36
		21	Huronia		82
		25	Huronia		60
		29	Sudbury		82
		32	Blind River	12, 49	12, 49
		63	Minden		67
		65	Minden	11, 13, 38	69
		66	Minden	5, 79	5, 79
		81	Tweed	60	60
		83	Napanee	66	66, 100
		90	Parry Sound	17, 47	17, 47
		92	Parry Sound	38	38
		103	Owen Sound	93	
By	Yellow Birch	37	Sault Ste. Marie	71	
		64	Minden	1, 20	
		67	Minden		43
		90	Parry Sound	63	6
		104	North Bay		4, 99
Cb	Black Cherry	2	Bracebridge	36	36, 41
		4	North Bay		86
		17	Parry Sound	40	
		24	Huronia		18
		50	Aylmer		27, 42
Or	Red Oak	29	Sudbury		88
		89	Parry Sound	42	
Bw	White Birch	23	Huronia		53
		89	Parry Sound	52	
Hb	Bitternut Hickory	50	Aylmer	97	64, 97
Po	Trembling Aspen	1	North Bay		67
		77	Wingham		31
Ab	Black Ash	104	North Bay		30, 56

TABLE 14: A SUMMARY OF DEAD (FALLEN) TREES BY SURVEY PLOT IN 1989 AND 1990 (Cont'd)

Species		Plot	MNR District	Dead Tree No. (1989)	Dead Tree No. (1990)
Pob	Balsam Poplar	38	Sault Ste. Marie		18
Pol	Largetooth Aspen	29	Sudbury		61
		69	Chatham		3
Ew	American Elm	11	Carleton Place	93	93
He	Hemlock	66	Minden	75	75
		104	North Bay		27, 94
Bf	Balsam Fir	18	Parry Sound		92
		32	Blind River	59	59
		40	Sault Ste. Marie	80, 90, 97	80, 90, 97
Pw	White Pine	33	Blind River	13	13
		53	Niagara	72	72
Ce	White Cedar	37	Sault Ste. Marie	95	95
		94	Espanola	27, 79	27

TABLE 15: A SUMMARY OF DEAD (FALLEN) TREES BY MNR ADMINISTRATIVE DISTRICT IN 1989 AND 1990

	Number of Dead Trees						Percentage of Dead Trees					
	1989			1990			1989			1990		
MNR District	Sugar Maple	Other	Total	Sugar Maple	Other	Total	Sugar Maple	Other	Total	Sugar Maple	Other	Total
North Central Region												
Thunder Bay	0	0	0	4	0	4	0.0	0.0	0.0	5.1	0.0	2.5
Northeastern Region												
Blind River	4	5	9	3	4	7	5.7	9.1	7.2	3.8	4.8	4.3
Espanola	7	4	11	5	5	10	10.0	7.3	8.8	6.3	6.0	6.1
North Bay	0	0	0	6	8	14	0.0	0.0	0.0	7.6	9.5	8.6
Sault Ste. Marie	4	7	11	4	8	12	5.7	12.7	8.8	5.1	9.5	7.4
Wawa	1	0	1	1	0	1	1.4	0.0	0.8	1.3	0.0	0.6
Algonquin Region												
Algonquin Park	5	0	5	4	1	5	7.1	0.0	4.0	5.1	1.2	3.1
Bancroft	4	3	7	1	0	1	5.7	5.5	5.6	1.3	0.0	0.6
Bracebridge	0	1	1	1	2	3	0.0	1.8	0.8	1.3	2.4	1.8
Minden	17	15	32	4	13	17	24.3	27.3	25.6	5.1	15.5	10.4
Parry Sound	8	7	15	5	6	11	11.4	12.7	12.0	6.3	7.1	6.7
Pembroke	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Central Region												
Cambridge	0	0	0	1	0	1	0.0	0.0	0.0	1.3	0.0	0.6
Huronia	0	1	1	0	7	7	0.0	1.8	0.8	0.0	8.3	4.3
Lindsay	3	0	3	1	1	2	4.3	0.0	2.4	1.3	1.2	1.2
Maple	0	0	0	1	0	1	0.0	0.0	0.0	1.3	0.0	0.6
Niagara	4	1	5	6	1	7	5.7	1.8	4.0	7.6	1.2	4.3

TABLE 15: A SUMMARY OF DEAD (FALLEN) TREES BY MNR ADMINISTRATIVE DISTRICT IN 1989 AND 1990 (Cont'd)

	Number of Dead Trees						Percentage of Dead Trees					
	1989			1990			1989			1990		
MNR District	Sugar Maple	Other	Total	Sugar Maple	Other	Total	Sugar Maple	Other	Total	Sugar Maple	Other	Total
Eastern Region												
Brockville	0	1	1	1	2	3	0.0	1.8	0.8	1.3	2.4	1.8
Carleton Place	0	1	1	0	1	1	0.0	1.8	0.8	0.0	1.2	0.6
Cornwall	0	1	1	4	2	6	0.0	1.8	0.8	5.1	2.4	3.7
Napanee	1	2	3	0	4	4	1.4	3.6	2.4	0.0	4.8	2.5
Tweed	2	1	3	3	2	5	2.9	1.8	2.4	3.8	2.4	3.1
Southwestern Region												
Aylmer	2	2	4	7	6	13	2.9	3.6	3.2	8.9	7.1	8.0
Chatham	1	0	1	3	2	5	1.4	0.0	0.8	3.8	2.4	3.1
Owen Sound	3	2	5	6	0	6	4.3	3.6	4.0	7.6	0.0	3.7
Simcoe	0	0	0	2	3	5	0.0	0.0	0.0	2.5	3.6	3.1
Wingham	0	1	1	0	2	2	0.0	1.8	0.8	0.0	2.4	1.2
TOTALS	70	55	125	79	84	163	100.0	100.0	100.0	100.0	100.0	100.0

When all species are combined, 26% of the 1989 mortality occurred in the Minden District, 12% in the Parry Sound District and approximately 9% in both the Espanola and Sault Ste. Marie Districts. The remaining Districts each contained only a small proportion of the total number of dead trees. Similar to that for maples, total 1990 species mortality was somewhat more dispersed within the Province. Minden District contained the greatest proportion of the provincial total (10.4%), followed by North Bay District (8.6%) and Aylmer District (8.0%).

4.1.2 Regional Decline Patterns

The plot-by-plot spatial (and temporal) pattern of hardwood decline has been discussed. It is also of interest to discuss decline within defined boundaries. For this purpose, mean DIs were computed by Forest Section and MNR Administrative Districts. Some of the regional patterns of decline have been discussed for MNR Districts. Further discussion will appear in this section.

4.1.2.1 Hardwood Decline by Forest Section

The hardwood survey plots lie within two forest regions in Ontario, as recognized by Rowe (1972):

- Deciduous Forest Region; and
- Great Lakes-St. Lawrence Forest Region.

There are a total of twelve Forest Sections occurring within these two Forest Regions. Both the Rainy River and Haileybury Clay Forest Sections, however, lie outside of the hardwood forest study area. The Timagami Forest Section which was examined as part of the 1989 Hardwood Decline Survey (BEAK, 1990) was removed from the 1990 study area due to the low density of sugar maple in the Section. The removal of the Timagami Forest Section from the 1990 study area has resulted in the southward movement of the northern boundary of the study area. This change in the northern boundary has reduced the study area by

approximately 24,200 km^2 to 172,000 km^2. The nine Forest Sections examined in the 1990 survey are shown in Figure 16.

The revision to the study area boundary required recalculation of the Thiessen polygons associated with the more northerly sample plots. Utilizing the new polygon boundaries, mean DIs were computed by apportioning individual plot means within each Forest Section. Mean DIs for each Forest Section in 1986, 1987, 1989 and 1990 are presented in Table 16. The highest DIs in 1990 and 1989 were found in the Georgian Bay and Sudbury-North Bay Sections. In 1987, the highest DIs were found in the Algonquin-Pontiac and Sudbury-North Bay Sections. In 1986, the Georgian Bay and Algoma Forest Sections had the highest DIs. Between 1989 and 1990, there was a marginal deterioration in tree health across the Province. Mean DIs increased by one decline class in both the Huron-Ontario and Middle Ottawa Sections while the mean DI decreased by one decline class in the Sudbury-North Bay Section. There were no changes in decline class between 1989 and 1990 for the remaining five Forest Sections. Mean DI values decreased within five Forest Sections between 1986 and 1990, indicating a general improvement in tree health. During this same period, mean DI values increased by only one unit within the Georgian Bay, Huron-Ontario and Middle Ottawa Sections, and remained unchanged in the Sudbury-North Bay Section.

4.1.2.2 Hardwood Decline by MNR Administrative Districts

A total of 28 MNR Administrative Districts were identified within the 1990 Ontario Hardwood Decline Survey study area (Figure 17). As discussed in the previous section, changes in the northern boundary of the study area required recalculation of the Thiessen polygons associated with each sample plot. Mean DIs for each MNR District in 1986, 1987, 1989 and 1990 are presented in Table 17. The Districts with the highest mean DIs in 1989 were Minden, Espanola and Parry Sound. In 1990, the highest mean DIs were reported in the Minden District. In 1987, the highest decline was reported in the Algonquin Park and Espanola Districts. Highest decline in 1986 was found in the Sault Ste. Marie and Parry Sound MNR Districts. Twenty of the twenty-two Districts showed increased decline

Figure 16:
Forest Sections in the Hardwood Decline Survey Area

TABLE 16: HARDWOOD DECLINE BY FOREST SECTION[1]

Forest Section	% of Total Study Area	No. of Plots Established Within Section	No. of Plots Used in Mean DI Calculation[2]	Mean Decline Index				Mean DI (1986-1990)	Mean DI Change[3]
				1986	1987	1989	1990		
Deciduous Region									
Niagara	15.9	20	25	14	13	6	8	10	-6
Great Lakes-St. Lawrence Region									
Algoma	7.2	11	11	17	16	13	14	15	-3
Algonquin-Pontiac	8.1	15	16	15	23	15	14	17	-1
Georgian Bay	12.4	12	29	17	18	18	18	18	1
Huron-Ontario	27.0	20	45	12	13	9	13	12	1
Middle Ottawa	9.9	7	14	13	14	10	14	13	1
Quetico	1.8	3	3	15	13	6	8	11	-7
Sudbury-North Bay	8.7	12	18	15	21	19	15	18	0
Upper St. Lawrence	9.0	10	12	12	9	5	9	9	-3
			Provincial Mean	14	15	11	13	13	-1

[1] As defined by Rowe (1972).
[2] Individual plot Thiessen polygons may be apportioned to more than one Forest Section.
[3] Change in mean DI in 1990 relative to 1986.

Figure 17: MNR Administrative Districts in the Hardwood Decline Survey Area

TABLE 17: HARDWOOD DECLINE BY MNR ADMINISTRATIVE DISTRICT AND REGION[1]

	% of Total Study Area	No. of Plots Established Within District/Region	No. of Plots Used in Mean DI Calculation[2]	Mean Decline Index				Mean DI (1986-1990)	Mean DI Change[3]
				1986	1987	1989	1990		
North Central Region									
Thunder Bay District	1.8	3	3	15	13	6	8	10	-7
Region Total	1.8	3	3	15	13	6	8	11	-7
Northeastern Region									
Blind River District	2.0	5	7	15	17	18	15	17	0
Espanola District	3.3	7	11	15	21	19	17	18	1
North Bay District	5.7	5	8	15	20	17	14	17	-1
Sault Ste. Marie District	3.6	5	7	19	18	14	17	17	-3
Sudbury District	4.5	5	7	16	23	18	16	18	0
Wawa District	2.0	1	2	14	12	7	9	11	-5
Region Total	21.1	28	30	16	20	16	15	17	-1
Algonquin Region									
Algonquin Park District	5.1	4	10	15	26	15	13	17	-2
Bancroft District	2.5	2	8	15	17	13	17	15	2
Bracebridge District	3.8	2	12	15	19	17	17	17	2
Minden District	2.8	5	10	16	14	20	22	18	6
Parry Sound District	4.2	7	8	18	20	19	16	18	-1
Pembroke District	4.6	2	7	14	18	10	16	15	2
Region Total	23.0	22	32	15	20	15	16	17	1

TABLE 17: HARDWOOD DECLINE BY MNR ADMINISTRATIVE DISTRICT AND REGION[1] (Cont'd)

	% of Total Study Area	No. of Plots Established Within District/Region	No. of Plots Used in Mean DI Calculation[2]	Mean Decline Index 1986	1987	1989	1990	Mean DI (1986-1990)	Mean DI Change[3]
Central Region									
Cambridge District	4.3	3	10	16	17	9	11	13	-5
Huronia District	4.2	8	13	13	13	8	10	11	-3
Lindsay District	4.2	5	7	7	7	12	13	10	6
Maple District	3.1	2	10	8	9	8	11	9	2
Niagara District	1.7	5	5	16	17	9	9	13	-7
Region Total	17.5	23	30	12	12	9	11	11	-1
Eastern Region									
Brockville District	2.2	3	5	10	4	5	8	7	-3
Carleton Place District	3.6	2	7	15	7	7	10	10	-5
Cornwall District	3.2	4	5	11	14	6	10	10	0
Napanee District	4.0	2	4	12	4	9	16	10	4
Tweed District	4.0	3	7	13	5	10	15	10	2
Region Total	17.0	14	16	12	7	8	12	10	0
Southwestern Region									
Aylmer District	4.1	4	10	16	17	8	10	13	-6
Chatham District	4.8	3	3	16	12	3	5	9	-11
Owen Sound District	4.7	7	11	11	14	5	11	10	0
Simcoe District	1.9	2	6	13	14	5	6	10	-7
Wingham District	4.2	4	9	13	16	7	13	12	1
Region Total	19.7	20	22	14	15	6	9	11	-5
			Provincial Mean	14	15	11	13	13	-1

1 DI values for MNR Districts are weighted independent of those for MNR Regions.
2 Individual plot Thiessen polygons may be apportioned to more than one MNR District or Region.
3 Change in mean DI in 1990 relative to 1986.

between 1989 and 1990. The decline was generally minimal, however, with the largest being an increase of seven decline units for Napanee. Although there was a general trend towards improved tree health from 1987 to 1989, the following Districts showed a deterioration in tree condition: Blind River, Minden, Lindsay, Brockville, Napanee and Tweed. Between 1986 and 1989, a larger number of Districts had declining mean DIs, i.e., Blind River, Espanola, North Bay, Sudbury, Bracebridge, Minden, Parry Sound and Lindsay.

4.1.3 Hardwood Decline and Wet Sulphate and Nitrate Deposition Zones

Atmospheric deposition of sulphate and nitrate varies widely across the Province. There is a deposition gradient from highest levels in the southwest, to lowest levels in the northwest (Figures 18 and 19 for wet sulphate and nitrate deposition, respectively). This pattern reflects the industrial concentration in southern Ontario, and the proximity to large U.S. centres in the lower Great Lakes basin and further south (McLaughlin et al., 1987).

Wet sulphate and nitrate loadings from 1981-1984 were superimposed on the mean DI maps for 1990, 1989, 1987 and 1986, i.e., Figures 5 to 8, respectively, to determine if the distribution of hardwood decline was related to either wet sulphate or nitrate deposition. The mean DI for each wet sulphate and nitrate deposition zone is listed, for 1986, 1987, 1989 and 1990, in Table 18. The zone of highest wet sulphate deposition, i.e., greater than 35 kg SO_4/ha/yr, had one of the lowest mean DIs (for 1986, 1987, 1989 and 1990). The highest mean DI occurred (for each of the four years) in the 15 to 20 kg/ha/yr deposition zone. Improved tree health was evident within all deposition zones between 1986, 1987 and 1989. For all zones except the 20-25 kg/ha/yr, there was a marginal reduction in tree health between 1989 and 1990. For the two extreme zones, i.e., less than 10 kg/ha/yr and greater than 35 kg/ha/yr, the improvement in health between 1986 and 1990 was considerable. This may be a result of decreased loadings of wet sulphate and wet nitrate (pers. comm., D. McLaughlin, 1992).

Figure 18: Mean Wet Sulphate Deposition Zones (1981–1984) in the Hardwood Decline Survey Area

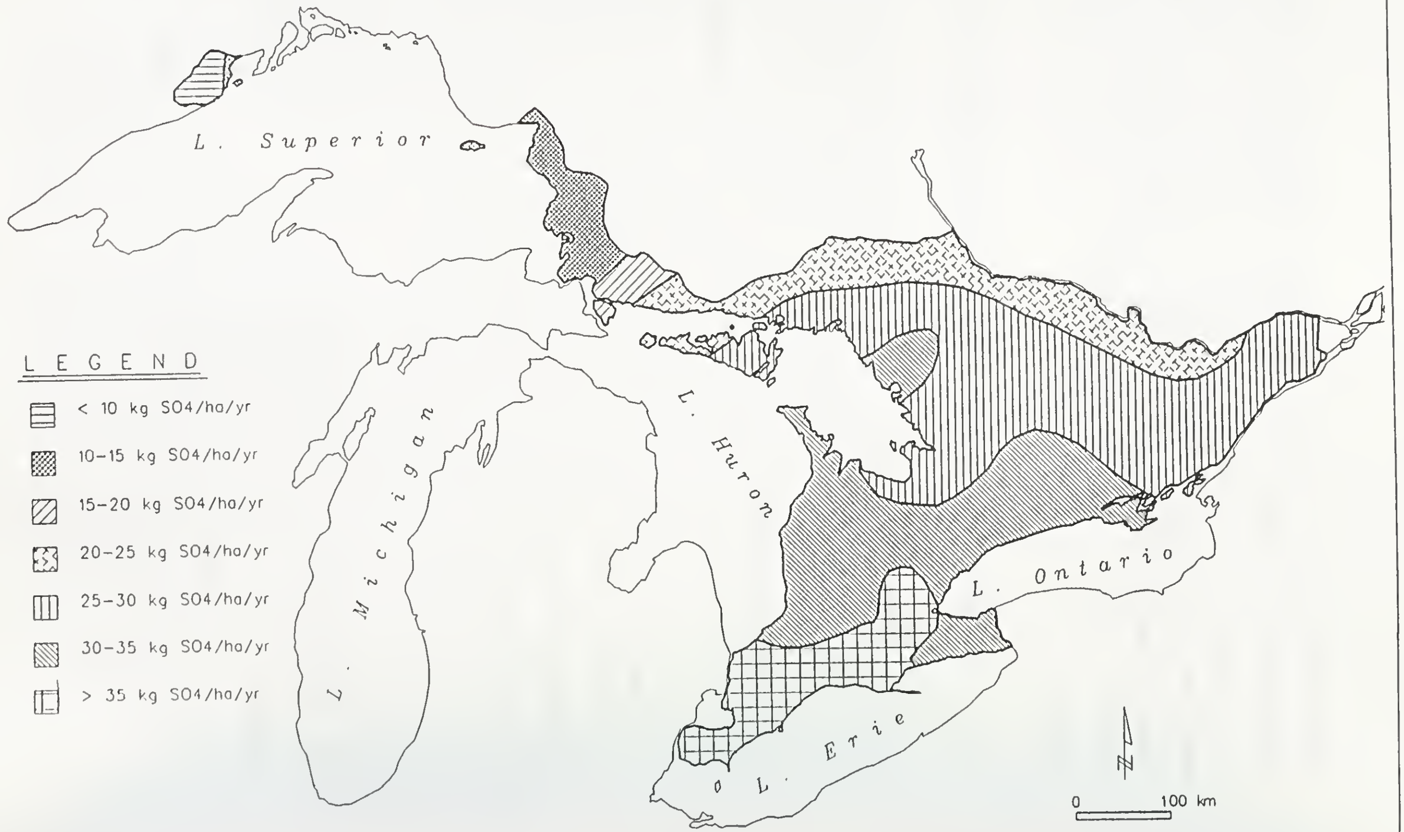


Figure 19: Mean Nitrate Deposition Zones (1981–1984) in the Hardwood Decline Survey Area

TABLE 18: HARDWOOD DECLINE AND WET SULPHATE AND NITRATE DEPOSITION

Deposition Zone (kg/ha/yr)	% of Total Study Area	No. of Plots Established Within Zone	No. of Plots Used in Mean DI Calculation[1]	Mean Decline Index				Mean DI (1986-1990)	Mean DI Change[2]
				1986	1987	1989	1990		
Mean Wet Sulphate Deposition									
Less than 10	1.7	3	3	15	13	6	7	10	-8
10-15	5.0	4	9	16	15	10	13	14	-3
15-20	1.8	3	4	22	22	19	20	21	-2
20-25	14.4	14	26	15	20	16	15	17	0
25-30	37.6	43	62	14	15	11	14	14	0
30-35	28.3	36	47	12	13	10	13	12	1
Greater than 35	11.3	7	13	16	14	5	7	11	-9
Mean Wet Nitrate Deposition									
1.5-2	5.0	6	7	15	13	7	9	11	-6
2-3	2.9	2	10	19	19	16	17	18	-2
3-4	18.0	18	30	15	21	15	14	16	-1
4-5	56.3	68	83	13	13	11	14	13	1
Greater than 5	17.7	16	26	15	15	7	9	12	-6

[1] Individual plot Thiessen polygons may be apportioned to more than one deposition zone.
[2] Change in mean DI in 1990 relative to 1986.

Generally, DI was inversely related to nitrate deposition, although the relationship was not as evident as for wet sulphate deposition. In all but the 1987 survey year, the highest DIs occurred in the 2 to 3 kg/ha/yr wet nitrate deposition zone. Marked improvements in tree health occurred between 1987 and 1989 for each wet nitrate deposition zone. Over the five year study period, the only nitrate deposition zone which exhibited a deterioration in mean DI values was the 4 to 5 kg/ha/yr zone; a marginal decrease of one decline unit was recorded in this zone.

It is apparent that there is no direct relationship between acidic deposition and hardwood forest condition. This is consistent with the literature and current theory. The relationship between acidic precipitation and forest health is believed to be much more obtuse, likely correlated with subtle adverse effects or soil chemistry rather than acute effects on the foliage. This survey was not designed nor intended to be a cause and effect investigation.

4.1.4 Quality Assurance Field Checks

<u>1989 Overlap Analyses</u>

Seven plots were selected at random for use as overlap test sites in 1989. Four plots were assessed by two field crews, and three plots were assessed by three crews. All assessments were conducted independently, i.e., crews were not informed that the plots had been previously assessed by another crew. Overlap plot assessment was conducted throughout the survey's duration.

The differences in mean plot DI generated by the various crews were examined statistically. The statistical analysis results are summarized in Table 19. Eight of the 13 paired plot assessments had a mean DI which varied by 5 or less. Only three of the 13 paired plot assessments had a mean DI which varied by more than 10, the greatest difference being 15. Regardless of the absolute difference in mean plot DI between assessments, none of these differences were statistically significant (p greater than 0.05).

TABLE 19: 1989 OVERLAP PLOTS - STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN CREW ASSESSMENTS

Survey Overlap Plot[1]	Mean Plot Decline Index Crew X**	Crew Y**	Difference in DI	Sum of Squares (SS)	Mean Square Error (MSE)	F Ratio*
2	22	16	6	315.0	541.8	0.58
17	27	12	15	776.5	541.8	1.43
26	19	14	5	244.5	541.8	0.45
26	14	9	5	220.0	541.8	0.41
26	19	9	10	464.5	541.8	0.86
36	13	11	2	142.5	541.8	0.26
36	13	11	2	143.0	541.8	0.26
36	13	13	0	0.5	541.8	0.0009
57	9	8	1	52.0	541.8	0.10
84	9	7	2	54.5	541.8	0.10
107	25	12	13	633.5	541.8	1.17
107	25	12	13	638.0	541.8	1.18
107	25	25	0	4.5	541.8	0.008

1 Plots 2, 17, 57 and 84 were overlapped by two crews and plots 26, 36 and 107 by three crews. For the latter set of plots, three comparisons are made between the three crews so that all combinations of crews were compared.

* In no case are differences between crews for decline index statistically significant (p greater than 0.05).

** Plot 2 was overlapped by crews 1 and 2; plot 17 by crews 2 and 3; plot 26 by crews 1, 2 and 3; plot 36 by crews 2, 3 and 4; plot 57 by crews 1, 2 and 3; plot 84 by crews 3 and 4; and plot 107 by crews 2, 3 and 4.

1990 Overlap Plot Analyses

Ten plots were selected at random for use as overlap test sites in 1990. Each of these plots was overlapped by each of the three crews. As with the 1989 analyses, all assessments were conducted independently, i.e., crews were not informed that the plots had been previously assessed by another crew. Overlap plot assessment was conducted throughout the survey's duration.

Two-way analysis of variance (ANOVA) tests were run using decline index and individual components of the decline index as the dependent variables, and crew, plot and crew-by-plot interaction, as the model effects. Planned comparisons between crews for mean decline index (across all overlap plots) were conducted where the crew-by-plot interaction effect was not significant. These single degree of freedom contrasts can be tested at a fixed probability level with considerably more power (of rejecting the null hypothesis that two means are equal) than multiple means tests. Where means are used in determining the planned contrast, the sums of squares attributable to the contrast are as follows:

$$SS = \frac{nL^2}{\Sigma\lambda_i^2}$$

where:

n = number of observations in the mean

L = the value of the contrast

λ_i = the ith coefficient of the contrast

This value divided by the mean square error gives the appropriate F-test with 1/n degrees of freedom. The results of ANOVA's for decline index and for the individual components of the decline index are summarized in Table 20. The results indicated that in the case of all dependent variables, with the exception of dead branches, there was a significant crew effect, i.e., less than 5% probability of incorrectly rejecting the null hypothesis that mean decline assessments for crews across all overlap plots are equal. The results of planned comparisons between crews for these variables are summarized in Table 21. The results

TABLE 20: RESULTS OF ANALYSIS OF VARIANCE: TWO-WAY ANALYSES OF VARIANCE INCLUDING BOTH MAIN AND INTERACTION EFFECTS FOR DECLINE INDEX AND VARIOUS COMPONENTS OF THE INDEX

		Dependent Variable (Pr > F)				
Source	Degrees of Freedom	Decline Index	Dead Branches	Slight Chlorosis	Strong Chlorosis	Small Leaves
Crew	2	0.03	0.07	0.0001	0.0001	0.0001
Plot	9	0.0001	0.0001	0.0001	0.0001	0.0165
Crew x Plot	18	0.99	0.99	0.0001	0.0001	0.0001

TABLE 21: PLANNED COMPARISONS BETWEEN CREWS FOR DECLINE INDEX (AND DEAD BRANCHES COMPONENT) AT OVERLAP PLOTS

	Difference Between Means (F Value for Planned Comparison)	
Crew Comparison	Decline Index	Dead Branches
1-3	2.04[1] (4.10)	1.45 (2.06)
1-2	2.50[1] (6.16)	2.30[1] (5.18)
3-2	0.46 (0.21)	0.85 (0.71)

[1] Difference between crews significant at the 5% level.

indicated that members of Crew 1 assigned trees significantly higher decline indices and percentage dead branches than Crew 2. Similarly, Crew 1 assigned higher decline indices to trees within overlap plots than Crew 3, although dead branch assessments between the crews were not significantly different. Crews 2 and 3 were statistically similar in their assessment of decline index and percentage dead branches across overlap plots. Plot effect also is significant for all dependent variables analyzed.

The crew-by-plot interaction effect was significant only for components of the decline index involving chlorosis and leaf size (Table 20). These components of the index are the most difficult to assess in the field and have correspondingly lower weightings in the decline index. The crew-by-plot interaction for these dependent variables suggests that individual crews assess chlorosis and leaf size differently depending on the plot visited. Given this interaction, it is not possible to statistically examine planned comparisons between crew means across all overlap plots.

5.0 CONCLUSIONS

Based on the findings of hardwood decline surveys conducted in 1986, 1987, 1989 and 1990, forest decline is evident in Ontario. Provincial mean decline indices of 14, 15, 11 and 13 were recorded in the 1986, 1987, 1989 and 1990 survey years, respectively. These values represent relatively low decline. Localized incidences of deterioration in tree health have been identified; however, hardwood forest decline does not appear to be a widespread problem within the Province.

Regional variations in forest condition are evident both within survey years and across the five-year study period. Severe decline was reported within only one plot in 1986, ten plots in 1987, seven plots in 1989 and three plots in 1990. All of these plots are located within the Northeastern and Algonquin MNR Administrative Regions. Severe decline was noted in two years at plots in the Espanola MNR District (1987, 1989) and the Minden District (1989, 1990). The Sudbury District was the only district to contain plots which showed consistent and severe decline in 1987, 1989 and 1990. These three districts are located within areas which possess physiographic associations, soil types, drainage regimes and vegetative conditions which are indicative of low hardwood forest productivity. Such conditions would tend to predispose hardwood species to decline symptoms.

No clear trend in decline levels is evident throughout the five-year study period. There was a marginal increase in the provincial mean decline index from 14 in 1986 to 15 in 1987. Extensive defoliation of hardwood species by forest insects in 1987 may have led to the classification of many study trees as dead. The overall effect of this insect defoliation may have attributed to the increased 1987 mean DI value. Overall, tree health appears to have improved between 1987 and 1989, as indicated by a decrease in mean DI values from 15 to 11. A modest increase in decline levels was evident between 1989 and 1990, as the provincial mean DI rose to 13 units.

Tree mortality levels were also variable over the study years. Tree mortality across all survey plots was 1.7% in 1986, 3.1% in 1987, 1.1% in 1989 and 1.5% in 1990. The total number of dead trees increased from 1986 to 1987, and from 1989 to 1990. There was a substantial decrease in the number of trees classed as dead from 1987 to 1989. The number of dead trees in 1986 was also higher than in 1989 and 1990. These mortality levels suggest that "normal" mortality in a hardwood forest ranges from 1 to 1.5%.

No direct relationship was apparent between acidic deposition and forest condition. The zone of highest wet sulphate deposition (35 kg SO_4/ha/yr) had one of the lowest annual mean DIs, whereas the highest annual mean DIs occurred in the zone which received 15 to 20 kg SO_4/ha/yr. Improved tree health was evident within all wet sulphate deposition zones between 1986 and 1989. For all zones except the 20 to 25 kg/ha/yr, there was a marginal reduction in forest health between 1989 and 1990. Generally, DI values are inversely related to nitrate deposition levels. In all but the 1987 survey year, the highest DIs occurred in the 2 to 3 kg/ha/yr wet nitrate deposition zone. Marked improvements in tree health occurred between 1987 and 1989 for each wet nitrate deposition zone.

The quality assurance field checks carried out in 1989 and 1990 indicate that the decline index rating methodology can be successfully applied within the Hardwood Decline Survey Program. Statistical analyses indicate that the assessment of foliar colour and size can vary significantly between field survey crews. The low weighting of these parameters within the decline index rating methodology is therefore justifiable.

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